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Assessment of the DoD Laboratory Civilian Science and Engineering Workforce

Jocelyn M. Seng, Project Leader
Pamela Ebert Flattau

June 2009
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IDA Paper P-4469
Log: H 09-000914

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Preface

The Institute for Defense Analyses (IDA) prepared this document for the Director, Defense Research and Engineering (DDR&E) under a task titled "Human Capital Technical Assessment for DoD Workforce of the Future." The task objective was to analyze trends in the civilian science and engineering (S&E) workforce employed by the DoD laboratories as input for policy and funding decisions relative to S&E workforce development to meet national security needs. Technical cognizance for this task is assigned to the Office of the Director, Defense Research and Engineering (DDR&E), and our primary contract monitor was Ms. Carolyn Nash. The IDA point of contact (POC) is Dr. Jocelyn Seng.

George C. Tolis and Michael A. Rigdon were the technical reviewers for this document. The authors acknowledge the following IDA Staff members who participated in this study: Darius Singpurwalla, George C. Tolis, Keri L. Dorman, Dennis M. Kowal, Margaret Boeckmann, Nyema Mitchell, Asha Balakrishnan, John C. Everett, Erika T. Tildon, Matthew T. Coursey, and Michael A. Yared. The authors would like to thank William S. Rees, Jr., John W. Fischer, Spiro Lekoudis, Laura D. Adolfie, Timothy T. Powers, Scott L. Segerman, Greg W.Riley, and Deborah Eitelberg for their contributions and suggestions. The authors also extend their thanks to the laboratory directors and their staff, who met with the authors.

Foreword

The U.S. Department of Defense (DoD) meets its needs for advanced military technologies through its access to skilled scientists and engineers (S&Es)[1] working in a variety of settings. Many of these specialists are employed by DoD laboratories (DoD labs) operated under the aegis of the U.S. Army, U.S. Navy, and U.S. Air Force. The civilian S&Es employed by DoD labs are the subject of this report.

The civilian S&E workforce employed by the Department of Defense (DoD) laboratories (DoD labs) represents a total of 35,400 workers in 2008,[2] these civilian S&Es play a critical role in national security by working at the forefront of science/engineering and technology breakthroughs. For example, Thomas Edison guided the first Naval Consulting Board, which pioneered the fields of high-frequency radio and underwater sound propagation. The history of modern computing can be traced to the need for increased speed and accuracy in firing, which led the Ballistics Research Laboratory to support the development of the first operational, general-purpose computer (i.e., ENIAC). Also, the core disciplines in aeronautical science, vehicle control technologies, and structures for all atmospheric and trans-atmospheric vehicles have made the Air Force laboratories leaders in the development of military aerospace vehicles. In every case, the DoD S&Es have taken the lead in advancing these technologies.

Over the past several decades, the number of civilian S&Es has declined, both in real numbers and relative to an increase in scientific and engineering contractors. Concerned by the implications of this changing workforce, DDR&E asked IDA to assess recent trends and the current status of the civilian S&E workforce. The overarching question is whether the DoD will have access to the pool of talent needed to ensure that it will keep pace with technology developments across the globe. The analysis that follows begins to shed light on those trends.

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1 Throughout this report, S&E is used as an acronym for “science and engineering” and “scientist and engineer.” When used in the plural form for the latter, it will appear as S&Es.

2 As of 2008, there were approximately 98,600 scientists and engineers (S&Es) in DoD, of which only one-third (36%) are in the DoD labs.

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Executive Summary

The Director, Defense Research and Engineering (DDR&E) tasked the Institute for Defense Analysis (IDA) to analyze the civilian science and engineering (S&E)[3] workforce employed by the Department of Defense (DoD) laboratories (DoD labs). The objective of the study was (1) to provide DDR&E an assessment of the recent trends/current status of the S&E workforce as input for policy and funding decisions relative to S&E workforce development to meet national security needs and (2) to present suggestions to DDR&E regarding policies and practices that will ensure future workforce viability. The principal tasks were to

- Determine the size and composition of current civilian S&E workforce in DoD science and technology (S&T) laboratories
- Identify recent trends in the S&E workforce and projected trends to 2020
- Estimate the anticipated future composition of the U.S. and DoD S&E workforces
- Assess current DoD workforce programs, policies, and practices relative to future S&E needs.

A customized database developed by IDA, which contains workforce information provided by the Defense Manpower Data Center (DMDC), was created to conduct the workforce analysis. Trends in the DoD Lab civilian S&E workforce between 1988 and 2008 were analyzed in 5-year increments. IDA augmented data analysis with selected DoD lab director interviews, in part to understand the role of "Lab Demo" [4] in shaping DoD S&T workforce personnel policies.

This report summarizes the study findings and recommendations.

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3 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

4 Lab Demo was initiated by DoD in 1995 to give lab directors new responsibility over the development of their lab civilian S&E workforce. It is discussed in more detail in Section III.D.1.

Finding 1: Workforce Quality

In 2008, the DoD labs civilian S&E workforce largely resembled the U.S. S&E workforce with some important differences. The DoD lab S&E workforce age profile is not flat, owing to the fact that the DoD lab workforce lacks workers between 35 and 45 following the hiring freeze in the 1990s and worker turnover. The DoD lab S&E workforce is also slightly older than U.S. S&E workforce but has a similar mix of workers when analyzed by race/ethnicity. However, the number of women S&Es employed by DoD labs has not kept pace with their growth in the U.S. S&E workforce as a whole.

Despite a detailed personnel data system, little is known about the *quality* of the S&E workforce within the DoD because pertinent data, such as educational disciplines, educational institutions, and employment history prior to DoD employment, are not recorded in the Defense Manpower Data Center (DMDC) database.

Recommendations

- **Additional DMDC data fields.** Develop additional data to support DoD lab S&E workforce quality assessment. Investigate the quality of the DoD Lab civilian S&E workforce for purposes of policy and planning. Database fields could be added to the DMDC records to include information about the source of new recruits (e.g., academia, including school and major; industry; government). Information about education and training history is also needed, with respect to the names of the educational institutions and types of formal post-degree training certificates that DoD lab civilian S&E staff may have received before joining the DoD workforce.
- **Quality metrics.** Compile and document quality of workforce metrics (such as number of patents, number of publications, number of requests for invited external presentations, number of citations) as a part of the annual data call for the DoD In-House S&T Activities Report.
- **Lab director survey.** Supplement the DMDC database with a formal survey/data call of DoD lab directors to collect additional information on workforce quality (update the 1990 IDA study).[5]

[5] Metzko, John, and Jesse Orlansky. *Study II of Scientists and Engineers in the DoD Laboratories*. IDA Paper P-2589 (Alexandria, VA: Institute for Defense Analyses, 1990).

Finding 2: Workforce Projections

DoD can expect to find qualified engineers in the coming years because degree production in engineering at all levels seems to be increasing in the United States. However, the number of U.S. computer science baccalaureates continues to decline after its peak in 2003, and the number of mathematics and physical sciences baccalaureates remains low. Significant uncertainties exist relative to degree production and employment in the sciences and engineering at this time—owing in part to changing economic circumstances and student career preferences. This situation suggests that DoD may experience problems when seeking qualified workers in those three scientific disciplines and should monitor trends through enhanced modeling work and scenario development.

Recommendations

- **Workforce modeling.** DoD should implement a formal workforce model to inform discussion and strengthen DoD strategic planning. The model should include a disaggregation of information at the occupational level to consider projection-based degree production and hiring and retention patterns for scientists vs. engineers and for individual disciplines.
- **Workforce development strategy.** The adequacy of current DoD S&E workforce recruitment and retention strategies can only be understood using various scenarios. IDA developed three possible scenarios[6] and found that each scenario generates a unique set of issues.

Finding 3: Workforce Management

DoD can expect that a significant portion of more experienced workers (early 50s) currently employed by DoD S&T labs will begin to retire in the next 5 years and will have left by 2020. The recent wave of new hires will most likely dominate the DoD civilian S&E workforce by 2020 as mid-career workers if recent patterns of recruitment and retention continue over the next 10 years. The Lab Demo directors reported to IDA that Lab Demo provides the kind of flexibility needed to implement personnel decisions responsive to current market conditions—locally and nationally.

6 (1) Downsizing, (2) maintain current workforce levels, and (3) increase the DoD lab S&E workforce.

Recommendation

- **Integration of Lab Demo outcomes into ongoing redesign of DoD Personnel Management System.** Update the 2002 *DoD Science and Technology Reinvention Laboratory Demonstration Program Summative Evaluation*[7] by validating Lab Demo observations as a result of this IDA study. Ensure that best practices and identified needs of all the DoD labs are fed into currently ongoing and subsequent work related to review of the National Security Personnel System to enable resulting policy direction that will meet the needs of the labs to develop a permanent personnel management system that works. Since there is urgency to deploy personnel management authorities necessary to sustain a robust S&E workforce, an interim solution for the DoD labs should be implemented if the current review of DoD's civilian personnel systems does not lead quickly to a broadly accepted conclusion.

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7 U.S. Department of Defense. *DoD Science and Technology (S&T) Reinvention Laboratory Demonstration Program: Summative Evaluation 2002*, (Washington DC, August 2002).

Section I.
Introduction

A. Objective and Tasks

The Director, Defense Research and Engineering (DDR&E) tasked the Institute for Defense Analysis (IDA) to analyze trends in the civilian science and engineering (S&E)[8] workforce employed by the Department of Defense (DoD) laboratories (DoD labs). The objective of the study was (1) to provide DDR&E an assessment of the recent trends/current status of the S&E workforce as input for policy and funding decisions relative to S&E workforce development to meet national security needs and (2) to present suggestions to DDR&E regarding policies and practices that will ensure future workforce viability. The principal tasks were to

- Determine the size and composition of current civilian S&E workforce in DoD science and technology (S&T) laboratories
- Identify recent trends in the S&E workforce and projected trends to 2020
- Estimate the anticipated future composition of the U.S. and DoD S&E workforces
- Assess current DoD workforce programs, policies, and practices relative to future S&E needs.

B. Findings in Brief

In 2008, the DoD labs civilian S&E workforce largely resembled the U.S. S&E workforce with some important differences. The DoD lab S&E workforce age profile is not flat, owing to the fact that the DoD lab workforce lacks workers between 35 and 45 following the hiring freeze in the 1990s and worker turnover. The DoD lab S&E workforce is also slightly older than U.S. S&E workforce but has a similar mix of workers when analyzed by race/ethnicity. However, the number of women S&Es employed by DoD labs has not kept pace with their growth in the U.S. S&E workforce as a whole.

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8 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

DoD can expect to find qualified[9] engineers in the coming years because degree production in engineering at all levels seems to be increasing in the United States. However, the number of U.S. computer science baccalaureates continues to decline after their peak in 2003, and the number of mathematics and physical sciences baccalaureates remains low. Significant uncertainties exist relative to degree production and employment in the sciences and engineering at this time—owing in part to changing economic circumstances and student career preferences. This situation suggests that DoD may experience problems when seeking qualified workers in those three scientific disciplines and should monitor trends through enhanced modeling work and scenario development.

DoD can expect that a significant portion of more experienced workers (early 50s) currently employed by DoD S&T labs will begin to retire in the next 5 years and will have left by 2020. The recent wave of new hires will most likely dominate the DoD civilian S&E workforce by 2020 as mid-career workers if recent patterns of recruitment and retention continue over the next 10 years. The Lab Demo[10] directors reported to IDA that Lab Demo provides the kind of flexibility needed to implement personnel decisions responsive to current market conditions—locally and nationally.

C. Background

The fundamental issue prompting the present study is a concern about pending S&E workforce retirements in the DoD labs. During the downsizing of the 1990s, DoD chose to shape its S&E workforce by restricting new hires. As a result, the workforce has aged, while the number of S&Es employed by DoD S&T labs has declined (Ref. 1). A new wave of younger workers hired in the past decade is now moving through the DoD lab workforce, even as the larger wave of mid-career workers is approaching retirement eligibility.

Two key questions emerge:

1. Will the DoD S&T labs have a sufficient number of younger S&Es in a state of readiness to deliver on the mission as older workers retire?
2. Is Lab Demo an adequate program to anticipate pending DoD labs civilian S&E workforce requirements through 2020 or are other DoD workforce strategies needed?

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9 Qualified: DoD presently requires U.S. citizenship as a basis for employment.

10 Lab Demo was initiated by DoD in 1995 to give lab directors new responsibility over the development of their lab civilian S&E workforce. It is discussed in more detail in Section III.D.1.

D. Structure of This Report

This report discusses IDA's assessment of the DoD labs' civilian S&E workforce. Section II describes the data sources and methods used. Section III presents the results of the analyses, presented in the context of the four task areas listed in Section I.A. Section IV provides findings and recommendations. Appendixes A through E provide more detail of selected elements of the study, Appendix F contains literature highlights, and Appendix G includes an extensive reading list.

Section II.
Data Sources and Methods

A. Data Sources

The principal source of workforce data used in this study was the personnel database maintained by the Defense Manpower Data Center (DMDC). DMDC provided IDA the files that captured S&E workforce data from the entire DoD civilian S&E workforce at 5-year intervals—beginning in 1978 and going through 2008. IDA used the DMDC data files to focus on DoD S&T labs to include the S&Es at all Naval Warfare Centers (Appendix A, Table A-1, lists the organizations). The study restricted the analysis to include only those S&E civilian occupations as defined by the Office of Personnel Management (OPM) and the National Science Foundation (NSF) (Ref. 2) (Appendix A, Table A-2, gives a list of the S&E occupations).

IDA supplemented its database analysis with workforce information gathered through interviews with DoD lab directors and their staffs (see Appendix B for further information). These interviews were conducted between December 2008 and February 2009 and provided important insights into DoD S&E workforce requirements and practices.

B. Methods

To analyze these data, IDA adopted a human workforce planning framework based on five key elements: requirements, recruiting, retention, retraining (refresh), and retirement.

Modeling was based, in part, on a definitive IDA report (Ref. 3) by Metzko and Orlansky: *Study II of Scientists and Engineers in the DoD Laboratories*.

C. Database Construction

The initial data set, generated by DMDC, selected all civilians who had an S&E occupation (defined in Appendix A, Table A-2) between 1978 and 2008. The data files were then given to IDA and loaded into a Microsoft Access database. For more detail, see Appendix A, Sections E and F.

In addition, the IDA database permitted a cohort[11] analysis of worker turnover patterns (see Appendix C). DMDC assigned each individual a unique ID, which IDA used to track the employment history of individuals over time. Thus, it was possible for IDA to generate series of tables to track the recruitment, retention, and retirement patterns of individuals during a particular time interval. Tracking tables were created for the year of interest by matching IDs on the previous time period and the subsequent time period. For example, for the 1993 recruiting, retention, and retirement statistics, the ID would be matched to the previous 5-year increment (1988) and the subsequent 5-year increment (1998). Once the tracking tables had been constructed, a set of queries was designed to identify new recruits and retirees by examining whether their DMDC ID could be found in the previous year (identifying new recruit) or the subsequent year (with absence interpreted as having retired).

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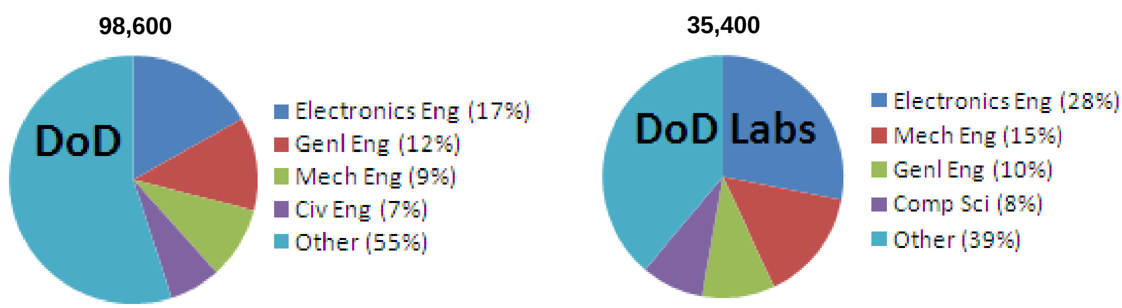
11 Defined here as a group of individuals who have a statistical factor (e.g., age, group membership) in common in a demographic study.

Section III.
Results

A. DoD Civilian S&E Workforce Size and Composition: 2008

The total 2008 DoD civilian S&E workforce had 98,600 employees. The 21 “DoD S&T Labs” that are the primary focus of this IDA study (see Appendix A, Table A-1) employed 35,400 (36%) of those employees. According to data reported by the NSF, most of the civilian S&Es employed by the DoD are engaged in work activities such as test and evaluation; planning; production; and installations, operations, and maintenance (Ref. 4). Civilian engineers outnumber scientists throughout DoD (62% vs. 38%) and are more numerous at DoD labs (74% vs. 26%). In general, engineers dominate the total U.S. S&E workforce (Ref. 2).

As shown in Figure III-1b, electronics engineering, mechanical engineering, general engineering, and computer science represent the largest occupations in DoD labs (accounting for 60% of all civilian lab S&E workers in 2008).



(a) DoD (b) DoD labs

Figure III-1. Most Populated Civilian S&E Occupations in 2008

In 2003,[12] 26% of all S&Es in the U.S. workforce were 50 years old or older. The DoD lab S&E workforce is slightly older, with nearly one-third of the DoD lab S&E personnel aged 50 years or older (the average age is 44). Due to hiring patterns over the past 20 years, the age profile of the DoD lab workforce is bimodal, as shown in

[12] As reported in the latest year for which such data are available. National Science Board. *Digest of Key Science and Engineering Indicators 2008* National Science Board Report NSB-08-2. (Arlington, VA: National Science Foundation, 2008).

Figure III-2, with over 20% of the S&E workers between the ages of 45 and 49 and over 15% under 30 years of age. In contrast, the age distribution of all the U.S. S&Es is relatively flat across the age groupings.

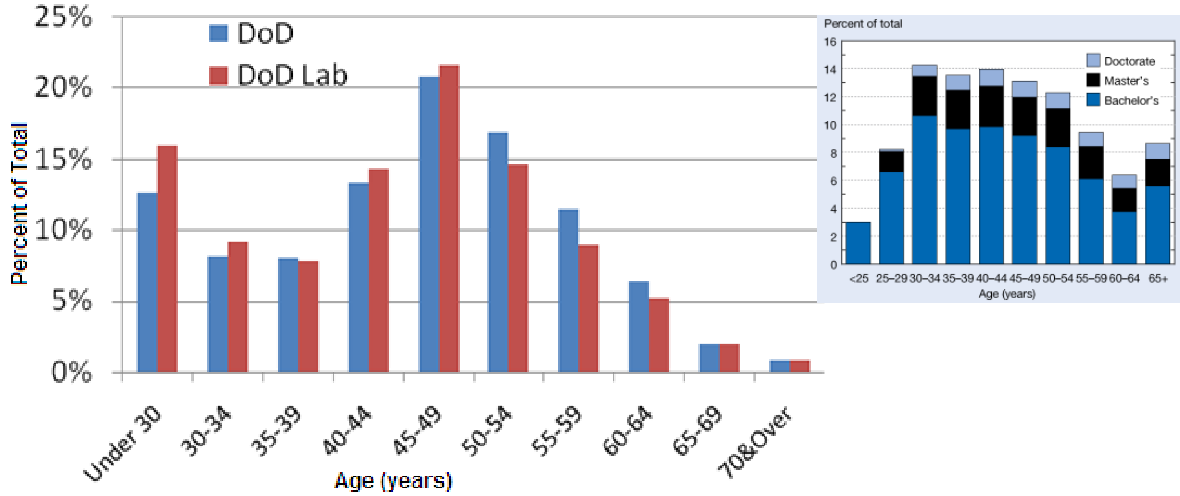


Figure III-2. DoD and DoD Lab Civilian S&E Workforce Age Profile in 2008

Note for Figure III-2: *The insert to the right shows the U.S. S&E workforce age profile in 2003 (Ref. 5).*

As was the case in the U.S. S&E workforce, baccalaureates dominate the DoD labs civilian S&E workforce in 2008, as shown in Figure III-3: 60% bachelors, 27% masters, and 10% PhDs. Comparable numbers for the U.S. non-academic S&E workforce in 2003 are 44% bachelors, 21% master's, and 7% PhDs.

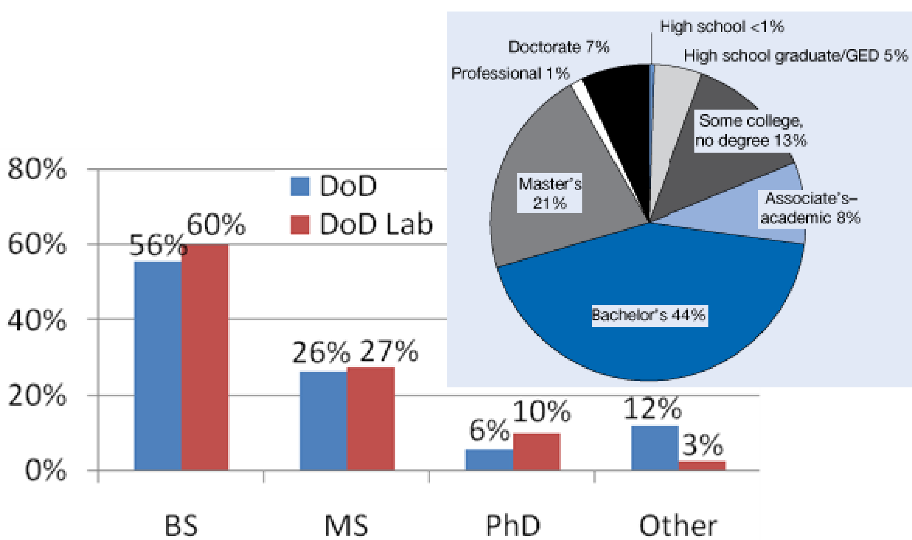


Figure III-3. DoD and DoD Lab Civilian S&E Workforce Education Levels in 2008

Note for Figure III-3: *The insert to the right shows the U.S. S&E workforce education levels (Ref. 5).*

For the 2,645 Air Force, 11,163 Army, and 21,585 Navy S&Es, Figure III-4 shows the educational degree level composition.

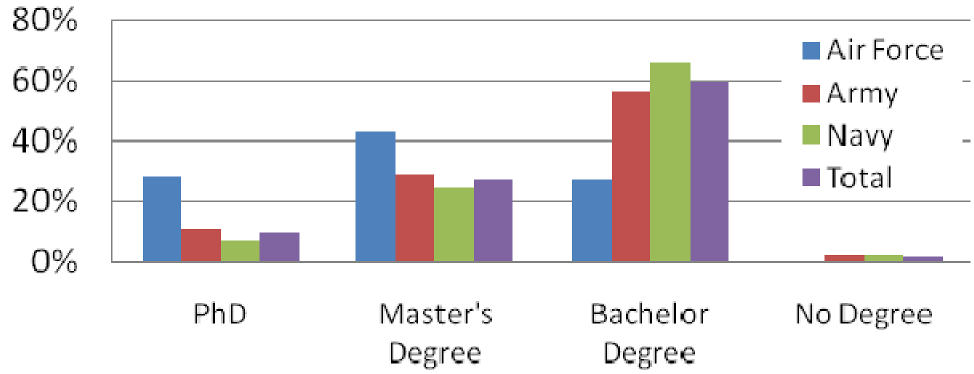


Figure III-4. DoD Lab Civilian S&E Workforce Education Levels by Service in 2008

Women comprised 26% of non-academic S&E workers in the United States in 2005, but represented just 16% of the DoD lab workforce in 2008, as indicated in Figure III-5. Women, on average, are 5 years younger than their male counterparts in DoD labs when compared at equivalent educational levels. Blacks and Hispanics each make up approximately 5% of U.S. non-academic S&E workers and also number in the same proportion among DoD lab workers. More data are provided in Appendix D.

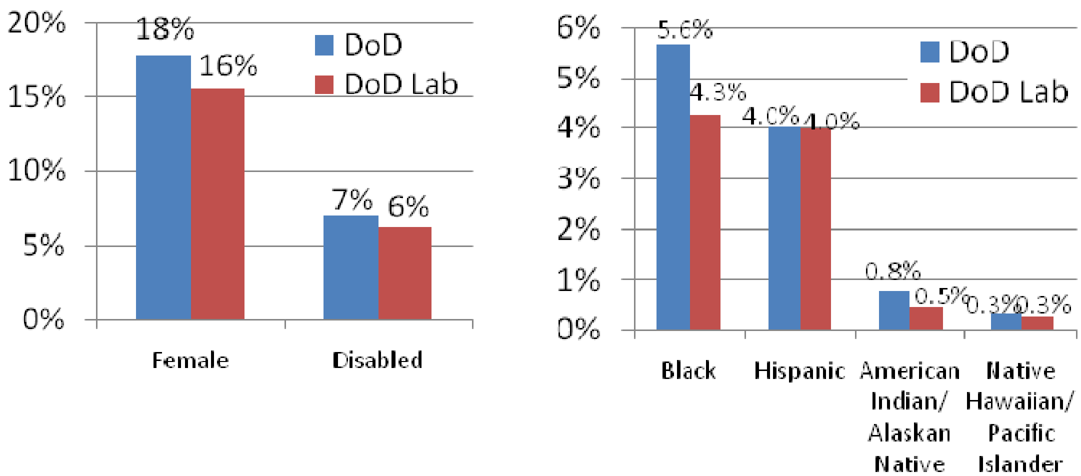


Figure III-5. Size of Underrepresented Groups
Within the DoD and DoD Lab Civilian S&E Workforce in 2008

B. Observations on Current and Projected Trends

While it is difficult to specify with confidence the future trends of the DoD S&T Lab workforce, it is possible to gain some perspective by documenting the rise and fall of certain occupations, cyclic hiring trends, worker turnover, and retirement patterns.

1. Trends in Top DoD S&E Occupations: 1998–2008

Table III-1 provides data that compare top S&E occupations in the Air Force, Army and Navy in 2008 and in 1998. The shaded areas highlight trends in selected occupations.

Several patterns are worth noting. Between 1998 and 2008,

- Aerospace engineering became one of the top five occupations in the Army, while computer science increased in prominence in all three Services.
- Physics generally declined as one of the top occupations in the Services, even as general engineering rose in prominence.

Table III-1. Top S&E Occupations by Service in 2008 and in 1998

2008								
Air Force			Army			Navy		
Occupation	Count	Percent of Total	Occupation	Count	Percent of Total	Occupation	Count	Percent of Total
Electronics Eng	761	28.8	General Eng	2,202	19.8	Electronics Eng	7,257	33.8
Aerospace Eng	357	13.5	Electronics Eng	1,840	16.5	Mechanical Eng	3,516	16.4
General Eng	258	9.8	Mechanical Eng	1,629	14.6	Computer Sci	2,278	10.6
Materials Eng	240	9.1	Computer Eng	858	7.7	Computer Eng	1,177	5.5
Physics	212	8.0	Aerospace Eng	559	5.0	Aerospace Eng	1,075	5.0
Computer Sci	144	5.4	Computer Sci	533	4.8	General Eng	1,026	4.8
Mechanical Eng	137	5.2	Gen Physical Sci	435	3.9	Physics	959	4.5
Computer Eng	106	4.0	Chemistry	340	3.1	Electrical Eng	690	3.2
Psychology	70	2.6	Chemical Eng	333	3.0	Mathematics	548	2.5
Chemistry	65	2.5	Ops Research	305	2.7	Ops Research	533	2.5
Total	2,350	89.0	Total	9,034	81.0	Total	19,059	89.0

1998								
Air Force 1998			Army 1998			Navy 1998		
Occupation	Count	Percent of Total	Occupation	Count	Percent of Total	Occupation	Count	Percent of Total
Electronics Eng	878	32.6	Electronics Eng	1,779	22.9	Electronics Eng	8,328	38.3
Aerospace Eng	431	16.0	General Eng	1,589	20.4	Mechanical Eng	3,087	14.4
Physics	223	8.3	Mechanical Eng	1,028	13.2	Comp Specialist	1,387	6.5
Materials Eng	215	8.0	Computer Eng	462	5.9	Computer Sci	1,385	6.4
Mechanical Eng	146	5.4	Civil Eng	309	4.0	Physics	1,201	5.6
General Eng	128	4.7	Physics	298	3.8	Aerospace Eng	902	4.2
Gen Physical Sci	84	3.1	Ops Research	253	3.3	General Eng	774	3.6
Computer Eng	80	3.0	Comp Specialist	244	3.1	Mathematics	680	3.2
Chemistry	72	2.7	Gen Physical Sci	238	3.1	Equip Services	593	2.8
Psychology	66	2.4	Computer Sci	206	2.6	Electrical Eng	386	1.8
Total	2,323	86.0	Total	6,406	82.0	Total	18,633	87.0

2. Cyclic Hiring Patterns

Due to the DoD's "peace dividend" hiring freezes in the 1990s, the age profile of the DoD lab S&E workforce is not flat. Figure III-6 shows the trends in the age profile over the last 20 years. Starting in 1988, there were two distinct age groups consisting of those born during 1943–1947 (Wave 1) and those around 1962 (Wave 2). By 2008, most of the Wave 1 personnel had retired, and the age profile is characterized by two distinct age groups at 47 years (Wave 2) and 30 years (Wave 3).Potential loss of the senior workers has become a source of concern for planners and policymakers. Two factors must be taken into consideration before drawing conclusions about the impact of this "bow" wave on the size and shape of the pool of DoD lab civilian S&E workforce: worker turnover and retirements.

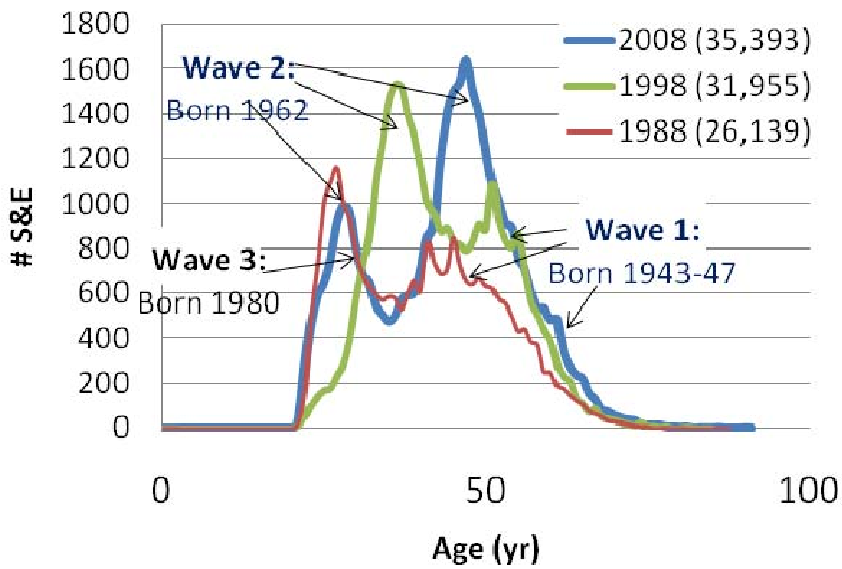


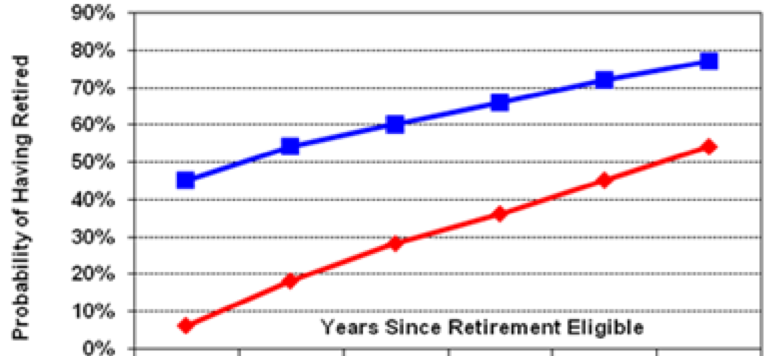
Figure III-6. Age Profile Trends of Civilian S&Es in DoD Labs in 1988, 1998, and 2008

a. Worker Turnover Trends

Worker turnover occurs in every organization. IDA tracked the retention of DoD lab civilian S&Es at 5-year intervals (see Appendix C). In general, the analysis revealed that about 20% of all civilian S&Es leave DoD employment after 5 years. Turnover is especially pronounced among younger S&Es when compared with turnover in other age groups. That is, by 2008, 74% of those under the age of 30 who represented "new hires" 5 years earlier remained in DoD, in contrast to well over 80% of "new hires" in other age categories. IDA also observed that scientists are more likely to leave DoD S&T lab employment than engineers (24% scientists vs. 18% engineers for the period 2003 to 2008).

b. Retirement Trends

Workforce planners must also anticipate retirement rates. As shown in Figure III-7, a recent IDA analysis has shown that about 54% of the retirement-eligible DoD S&E workforce has retired within 6 years of eligibility (Ref. 6). Retirement patterns are similar to that of the U.S. S&E workforce (Ref. 5).

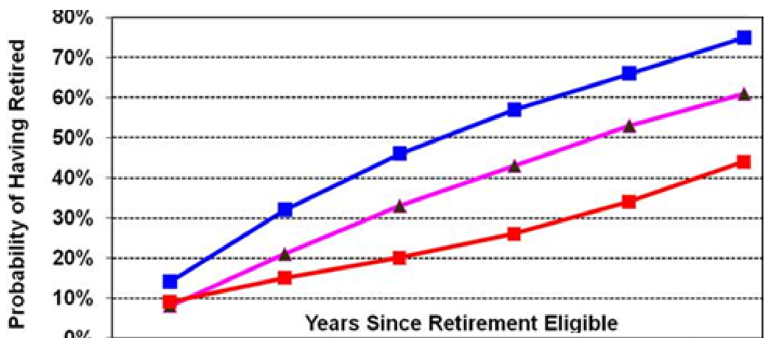


	1	2	3	4	5	6
Eng/Sci	0.06	0.18	0.28	0.36	0.45	0.54
Other	0.45	0.54	0.60	0.66	0.72	0.77

Figure III-7. Retirement Trends of DoD Civilians by Occupation

Source: Reference 6.

Figure III-8 shows the effects of different retirement plans. The retirement probability for those under the Federal Employees Retirement System (FERS) plan is distinctly lower than for the Civil Service Retirement System (CSRS) plan.



	1	2	3	4	5	6
CSRS w/o Penalty	0.14	0.32	0.46	0.57	0.66	0.75
FERS w/o Penalty	0.08	0.21	0.33	0.43	0.53	0.61
FERS w/ Penalty	0.09	0.15	0.2	0.26	0.34	0.44

Figure III-8. Retirement Trends of DoD Civilians by Federal Retirement Plan

Source: Reference 6.

A significant portion of more experienced workers (early 50s) can be expected to begin retiring in the next 5 years, and a large share of the current 45-to-50 age group will

have left completely by 2020. However, the effects of recent changes in the U.S. economy may delay retirements and possibly increase overall retention rates.

C. Anticipated Composition of the Workforce in 2020

While it is difficult to specify with confidence the composition of the DoD S&T lab workforce by the year 2020, recent recruitment trends at least point to the rise and fall of certain occupations that may anticipate near-term hiring needs and choices. In this section, we present three potentially informative indicators: resurgence of key occupations, degree production, and retirement patterns.

1. The Resurgence of Key Occupations in 2008

The DoD lab S&E workforce experienced a recent hiring resurgence in six prominent occupations (electronics engineering, mechanical engineering, computer science, computer engineering, electrical engineering, and operations research), as inferred from the new wave of younger workers in select occupations shown in Figure III-9.

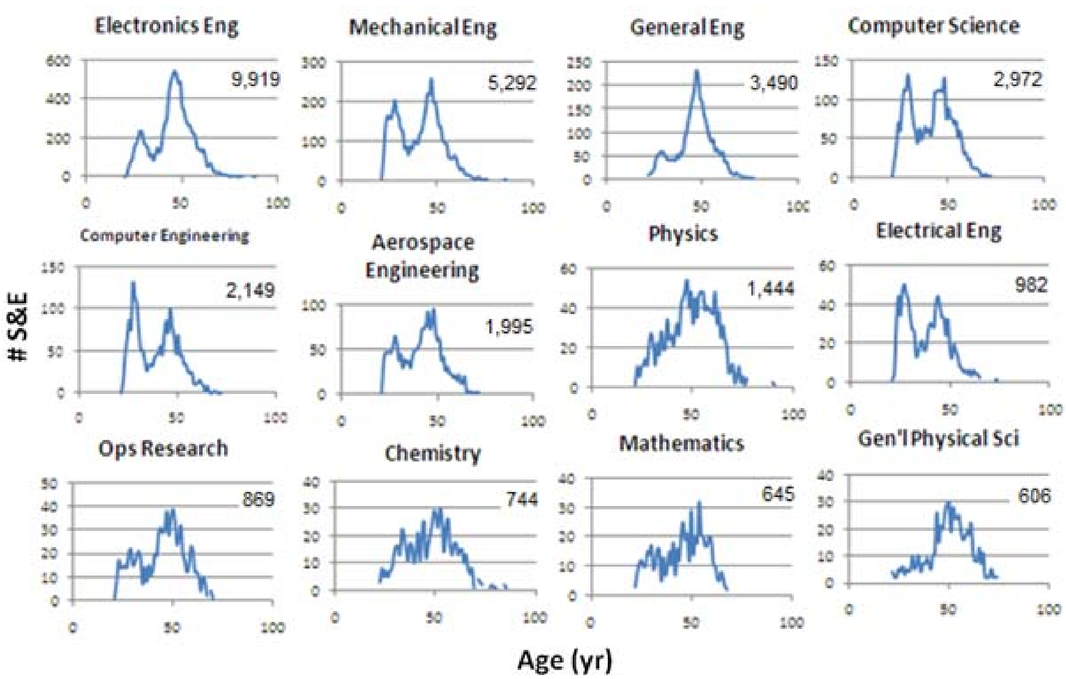


Figure III-9. Age Profiles of the Top 12 Civilian S&E Occupations in DoD Labs in 2008

Note for Figure III-9: *The numbers in the upper right corner of each graph (e.g., 9.919, 2,149, 869, and so forth) indicate the total number of DoD lab civilian S&Es employed in that occupation in 2008.*

When the workforce profiles for the top four DOD S&E occupations in 2008 are analyzed by degree level and age of the worker (see Figure III-10), it is clear that DoD

chiefly hires bachelor's and master's recipients in those top occupations. Some of the DoD Lab Directors interviewed by IDA as part of this project indicated that the advantage of recruiting baccalaureate degree recipients is that the laboratory staff can then provide on-the-job training to address the research topics of specific interest to the lab.

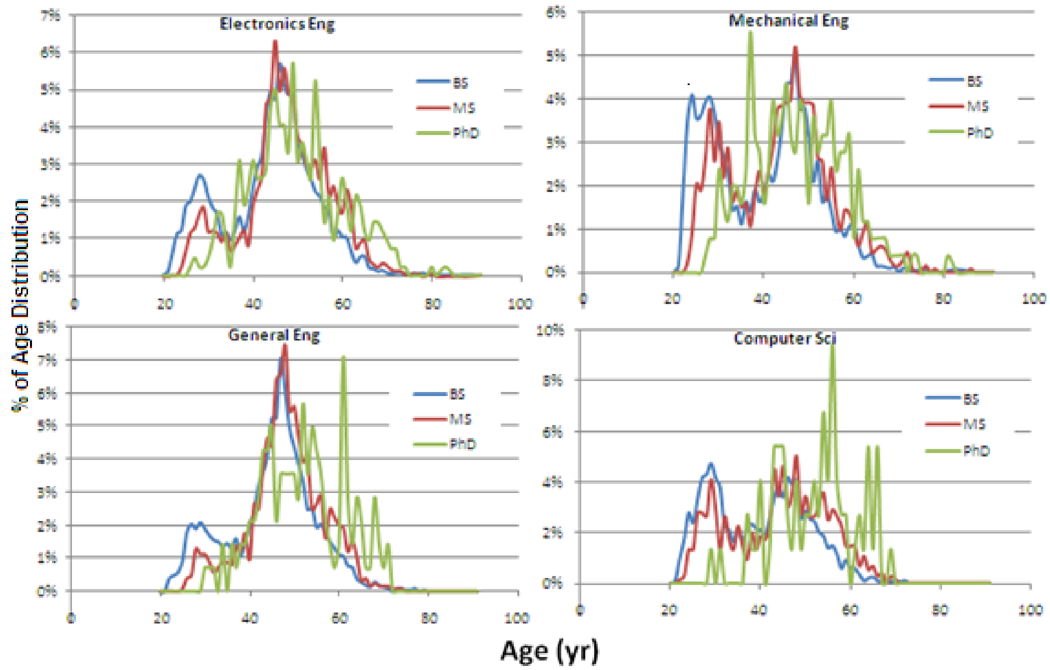


Figure III-10. Age Profile by Education Level for the Top 4 Civilian S&E Occupations in the DoD Labs in 2008

2. Degree Production in the Top DoD S&E Occupations

U.S. degree trends indicate that the number of degrees awarded to U.S. citizens through 2006 was on the rise in most subfields and at most degree levels in engineering. However, as shown in Figure III-11, the number of U.S. computer science baccalaureates continued to decline after reaching peak in 2003, and the number of mathematics and physical sciences baccalaureates remained constant but low. In fact, a recent report by The Conference Board[13] revealed that there were more vacancies than unemployed people seeking positions in computer and mathematical sciences in June 2009 (Ref. 7).

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13 From the Conference Board Web site (http://www.conference-board.org/): The Conference Board creates and disseminates knowledge about management and the marketplace to help businesses strengthen their performance and better serve society. Working as a global, independent membership organization in the public interest, we conduct research, convene conferences, make forecasts, assess trends, publish information and analysis, and bring executives together to learn from one another

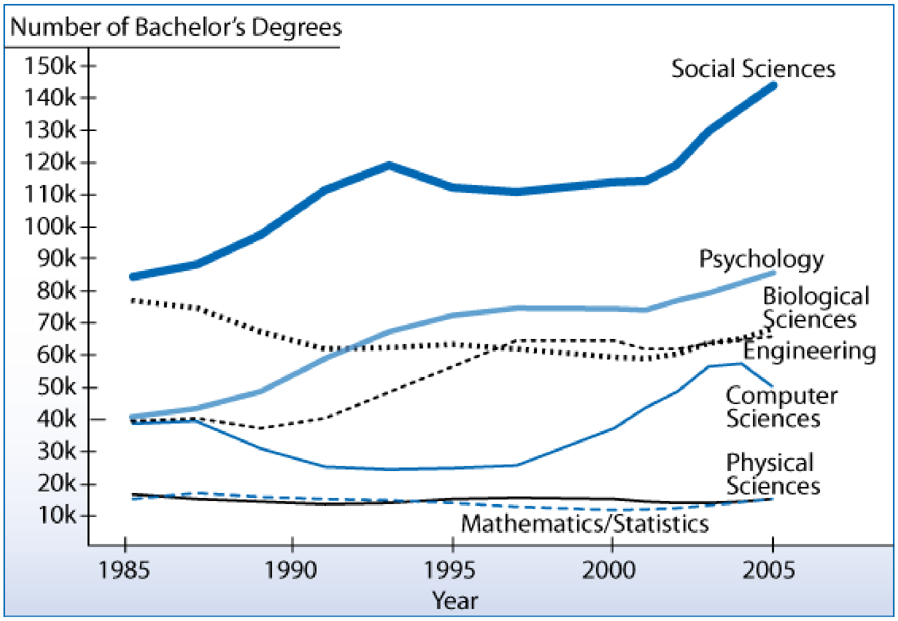

Figure III-11. Number of Bachelor's Degrees by Degree Field: 1985–2005

Source: Reference 8.

More detail on U.S. science and engineering degree awards, contrasting also U.S. citizens and temporary citizens, is given in Appendix E.

For further exploration, additional insight on S&E personnel requirements can be gleaned from existing DoD planning documents. Examination of position vacancies (unfilled billets) in organizational unit manning documents (UMDs) may highlight trends in specific hiring needs. More detailed discussions with DoD lab directors about future hiring projections could indicate whether there is a continuing interest in the top fields where shortages may exist and/or whether the emergence of some other occupations is on the rise.

3. Retirement Patterns and the Workforce Composition in 2020

IDA could find no evidence to indicate an imminent large-scale loss of DoD civilian S&Es due to retirement. However, the notable wave of DoD lab S&Es now in their early 50s will approach retirement eligibility in 5 to 10 years. Therefore, DoD will need to examine its recruitment and retention efforts to maintain the size and quality of its laboratory workforce in anticipation of workforce changes over the next decade.

The solid lines in Figure III-12 indicate age profile trends of the DoD labs' civilian S&E workforce over the last 20 years. Assuming as a baseline 100% retention

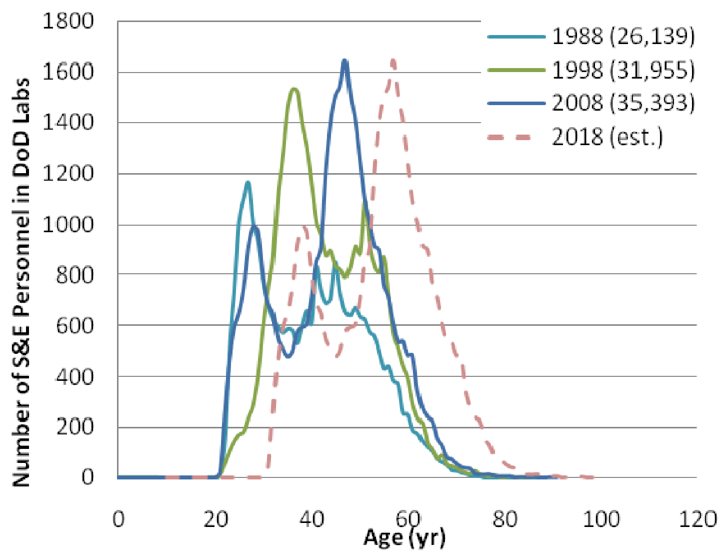

Figure III-12. Estimated 2018 Age Profile

Note for Figure III-12: *This estimated profile assumes static workforce: 100% retention and no new hires.*

and no new hires, the current age profile can be aged 10 years and results in the 2018 age profile projection, indicated by the dashed line in Figure III-12. Through pattern matching that is consistent with past retirement trends, Figure III-13 shows a more credible notional 2018 age profile. The notional 2018 age profile reflects a 12% decrease in workforce size.

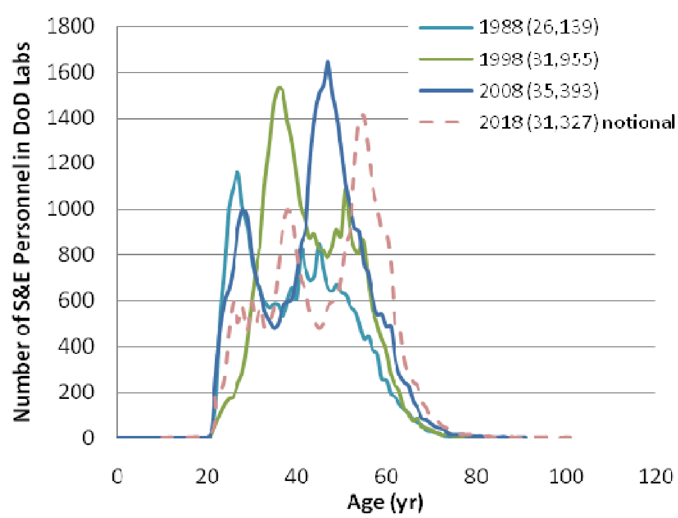

Figure III-13. Notional 2018 Age Profile

Note for Figure III-13: *This notional profile is aged and combined with pattern-matching new-hire estimates and retention estimates.*

D. Adequacy of Current S&E Workforce Strategy

1. DoD S&T Laboratory Demonstration Program

The DoD S&T Laboratory Demonstration Program (Lab Demo) (Ref. 9) represents a unique effort by DoD to provide participating laboratories the personnel management flexibilities needed to bolster a diminished workforce. An outcome of the DoD's Laboratory Quality Improvement Program, Lab Demo was authorized by section 342 of the National Defense Authorization Act for Fiscal Year 1995 (P.L. 103-337) as a demonstration project but without an expiration date. Each participating laboratory (see Appendix A, Table A-1) has uniquely implemented Lab Demo to meet its employment needs. Lab Demo has provided increased management flexibility for human resource planning in all five areas[14] of our workforce planning framework. It aids laboratories in dealing with uncertainty in workforce trends and future demand requirements. It also increases the management flexibility and responsiveness by expanding the authorities and capabilities to shape workforce. For example, some Lab Demo programs establish pay bands beyond GS-15 to attract/retain senior S&T experts.

IDA was interested in whether Lab Demo personnel management flexibilities have resulted in quantifiable improvement in retention statistics. The analysis approach was to compare the retention rates of new hires before Lab Demo implementation and the retention rates after Lab Demo implementation. Table III-2 summarizes the results, which indicate only a marginal improvement in retention statistics. However, we realized that retention rates are just a first-cut, crude measure. In fact, lab directors have the authority to release staff who are underperforming, which confounds the retention statistic. If anything, patterns merit closer attention at the lab level for understanding the ratio of retention to release rates.

Table III-2. Comparison of S&E Retention Rates of New Hires Corresponding to Pre- and Post-Lab-Demo Implementation (for Selected Laboratories)

	Percent Retention		
	From 1988 to 1993	**From 1998 to 2003**	**From 2003 to 2008**
Army Research Lab (1998)	76.3%	78.9%	78.4%
Air Force Research Lab (1997)	76.5%	76.5%	81.2%
Naval Research Lab (1999)	–	72.9%	75.2%

Note for Table III-2: *The dates in parentheses indicate the year the lab entered Lab Demo.*

14 Requirements, recruitment, retention, retraining (refresh), and retirement.

Lab Demo has been well received according to the lab directors interviewed by IDA and consideration should be given to offering it as an option to non-Lab Demo labs. The general consensus was that Lab Demo is a great start in increasing personnel management flexibilities, but it still needs to expand several essential capabilities and authorities—for example, relative to the speed of recruiting and competitive salaries. From the interviews, it seems that the DoD lab S&E workforce strategy needs to be more fully developed and should include modeling for evidence-based decision-making.

IDA interviews with lab directors/staff also revealed that DoD should consider

- Expanding authorization for direct-hire authority (aid to recruiting)
- Increasing bonus flexibility (to compensate for pay compression)
- Encouraging liberal use of Interagency Personnel Agreements (IPAs) to address needs for mid-career staff
- Developing a better mechanism and budget flexibility—augmenting current Military Construction (MilCon)—to address/update obsolete infrastructure.

Lab directors also indicated that increased student-based awards programs would be beneficial. Labs do take advantage of existing programs (e.g. post-doc, intern, continuing education), and supplement needs with recruiting.

2. Three Workforce Scenarios

The adequacy of current S&E workforce policies and procedures (including Lab Demo) can be assessed using workforce scenarios. For possible future assessment consideration, three scenarios are:

1. **Downsizing.** If a downsizing in workforce (or, conservatively, no new hires) occurs, the issue to address will be the bulk of the workforce in their 50s who may be retiring within 10 years, resulting in a diminished workforce size. One option is to focus on the accelerated development of the younger cohort of baccalaureate S&Es, through mentoring, knowledge transfers, and greater degree advancement.
2. **Maintain current workforce levels.** If the current hiring levels are sustained, the issue to address is mid-career and young staff retention. One policy option is to expand mid-career hiring to anticipate pending retirements.
3. **Increase the DoD lab S&E workforce.** If the hiring levels are increased (particularly in emerging specialized fields), the issue to address is the restriction to hiring only U.S. citizens. The possibility of recruiting foreign hires in highly specialized fields is excluded because of the need for security clearances. A policy option would be to increase graduate awards in fields of anticipated DoD need (to compensate for the declining U.S. student interest in S&E).

Section IV.
Findings and Recommendations

Finding 1: Workforce Quality

In 2008, the Department of Defense Laboratories (DoD labs) civilian science and engineering (S&E) workforce largely resembled the U.S. S&E workforce with some important differences. The DoD lab S&E workforce age profile is not flat, owing to the fact that the DoD lab workforce lacks workers between 35 and 45 following the hiring freeze in the 1990s and worker turnover. The DoD lab S&E workforce is also slightly older than U.S. S&E workforce but has a similar mix of workers when analyzed by race/ethnicity. However, the number of women scientists and engineers (S&Es) employed by DoD labs has not kept pace with their growth in the U.S. S&E workforce as a whole.

Despite a detailed personnel data system, little is known about the *quality* of the S&E workforce within the DoD because pertinent data, such as educational disciplines, educational institutions, and employment history prior to DoD employment, are not recorded in the Defense Manpower Data Center (DMDC) database.

Recommendations

- **Additional DMDC data fields.** Develop additional data to support DoD lab S&E workforce quality assessment. Investigate the quality of the DoD Lab civilian S&E workforce for purposes of policy and planning. Database fields could be added to the DMDC records to include information about the source of new recruits (e.g., academia, including school and major; industry; government). Information about education and training history is also needed, with respect to the names of the educational institutions and types of formal post-degree training certificates that DoD lab civilian S&E staff may have received before joining the DoD workforce.
- **Quality metrics.** Compile and document quality of workforce metrics (such as number of patents, number of publications, number of requests for invited external presentations, number of citations) as a part of the annual data call for the DoD In-House S&T Activities report.
- **Lab director survey.** Supplement the DMDC database with a formal survey/data call of DoD lab directors to collect additional information on workforce quality (update the 1990 IDA study (Ref. 3)).

Finding 2: Workforce Projections

DoD can expect to find qualified engineers in the coming years because degree production in engineering at all levels seems to be increasing in the United States. However,

the number of U.S. computer science baccalaureates continues to decline after their peak in 2003, and the number of mathematics and physical sciences baccalaureates remains low. Significant uncertainties exist relative to degree production and employment in the sciences and engineering at this time—owing in part to changing economic circumstances and student career preferences. This situation suggests that DoD may experience problems when seeking qualified workers in those three scientific disciplines and should monitor trends through enhanced modeling work and scenario development.

Recommendations

- **Workforce modeling.** DoD should implement a formal workforce model to inform discussion and strengthen DoD strategic planning. The model should include a disaggregation of information at the occupational level to consider projection-based degree production and hiring and retention patterns for scientists vs. engineers and for individual disciplines. The Office of the Secretary of Defense (Personnel and Readiness) (OSD(P&R)) could mandate the development of a special model for DoD labs.
- **Workforce development strategy.** The adequacy of current DoD S&E workforce recruitment and retention strategies can only be understood using various scenarios. IDA developed three possible scenarios[15] and found that each scenario generates a unique set of issues.

Finding 3: Workforce Management

DoD can expect that a significant portion of more experienced workers (early 50s) currently employed by DoD S&T labs will begin to retire in the next 5 years and will have left by 2020. The recent wave of new hires will most likely dominate the DoD civilian S&E workforce by 2020 as mid-career workers if recent patterns of recruitment and retention continue over the next 10 years. The Lab Demo directors reported to IDA that Lab Demo provides the kind of flexibility needed to implement personnel decisions responsive to current market conditions—locally and nationally.

Recommendation

- **Integration of Lab Demo outcomes into ongoing redesign of DoD Personnel Management System.** Update the 2002 *DoD Science and Technology Reinvention Laboratory Demonstration Program Summative Evaluation* (Ref. 10) by validating Lab Demo observations as a result of this IDA study. Ensure that best practices and identified needs of all the DoD labs are fed into currently ongoing and subsequent work related to review of the National Security Personnel System to enable resulting policy direction that will meet the needs of the labs to develop a permanent personnel management system that works. Since there is urgency to deploy personnel

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15 (1) Downsizing, (2) maintain current workforce levels, and (3) increase the DoD lab S&E workforce.

management authorities necessary to sustain a robust S&E workforce, an interim solution for the DoD labs should be implemented if the current review of DoD's civilian personnel systems does not lead quickly to a broadly accepted conclusion.

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Glossary

AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AMRDEC	Aviation and Missile Research Development and Engineering Center (U.S. Army)
AMS	American Mathematical Society
AMSAA	Army Material Systems Analysis Activity
APG	Aberdeen Proving Ground
ARDEC	Armament Research, Development, and Engineering Center
ARI	Army Research Institute for the Behavioral and Social Sciences
ARL	Army Research Laboratory
ASB	Army Service Board
ASN(RE&S)	Assistant Secretary of the Navy/Research, Engineering and Science
CERDEC	Communications-Electronics Research, Development, and Engineering Center (U.S. Army)
CIMS	Center for Innovation Management Studies
CAN	Center for Naval Analyses
CRP	Central Research Project
CSRS	*Civil Service Retirement System*
DDR&E	Director, Defense Research and Engineering
DLA	Defense Logistics Agency
DLF	Direct Laboratory Funding
DMDC	Defense Manpower Data Center
DoD	Department of Defense
DoE	Department of Energy
DSB	Defense Science Board
DSS	Defense Security Service
DTIC	Defense Technology Information Center
ERDC	Engineer Research and Development Center (U.S. Army)
FERS	Federal Employees Retirement System
FY	Fiscal Year
GAO	General Accountability Office
GDP	gross domestic product
GGD	General Government Division (GAO)
GOCA	Government Operated, Contractor Assisted

GOCO	Government-Owned, Contractor-Operated
GS	General Schedule
IDA	Institute for Defense Analyses
IG	Inspector General
IPA	Interagency Personnel Agreement
IRI	Industrial Research Institute
MEB	Mission Element Board
MilCon	Military Construction
MRTFB	Major Range and Test Facility Base
NAS	National Academy of Sciences
NAWC	Naval Air Warfare Center
NBER	National Bureau of Economic Research
NDIA	National Defense Industrial Association
NDU	National Defense University
NHRC	Naval Health Research Center
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NMRC	Naval Medical Research Center
NRAC	Naval Research Advisory Committee
NRL	Naval Research Laboratory
NSB	National Science Board
NSF	National Science Foundation
NSIAD	National Security and International Affairs Division
NSWC	Naval Surface Warfare Center
NUWC	Naval Undersea Warfare Center
OCE	Office of Compliance and Enforcement
OPM	Office of Personnel Management
OTA	Operational Test Agency
OSC	Operational Support Command
OSD	Office of the Secretary of Defense
OSD(P&R)	Office of the Secretary of Defense (Personnel and Readiness)
P.L.	Public Law
PhD	Philosophiæ Doctor (Doctor of Philosophy)
R&D	research and development
RDEC	Research Development and Engineering Center
RDT&E	research, development, test, and evaluation
S&E	science and engineering scientist and engineer
S&T	science and technology
SAB	Scientific Advisory Board
SPAWAR	Space and Naval Warfare Systems Command

SSC	Space and Naval Warfare Systems Center
STTC	Simulation and Technology Training Center (U.S. Army)
TARDEC	Tank-Automotive Research, Development and Engineering Center
TR	Technical Report
U.S.	United States
UIC	Unit Identification Code
UMD	unit manning document
USAMRMC	U.S. Army Medical Research and Materiel Command
USASMDC	U.S. Army Space and Missile Defense Command
USDRE	Under Secretary of Defense for Research and Engineering
USPS	United States Postal Service
VCNO	Vice Chief of Naval Operations
VERA	Voluntary Early Retirement Authority
VIGRE	Vertical Integration of Research and Education in the Mathematical Sciences
VSIP	Voluntary Separation Incentive Program
VTC	Video Teleconferencing

Appendix A.
Defining the Population of Interest

The Department of Defense (DoD) laboratories (DoD labs) civilian science and engineering (S&E)[1] workforce is the population of interest for this study. As represented in Figure A-1, from the Defense Manpower Data Center (DMDC) civilian database of all DoD employees, the population of interest was defined by selecting those employees who were in the DoD labs (defined by the Unit Identification Code (UIC)) and in a scientist or engineer occupation (defined the occupational code). As of 2008, approximately 98,600 scientists and engineers (S&Es) were in DoD, of whom only one-third (36%) are in the DoD labs. From another perspective, approximately 61,400 civilian employees are in the DoD labs, of whom more than half (58%) are S&Es.

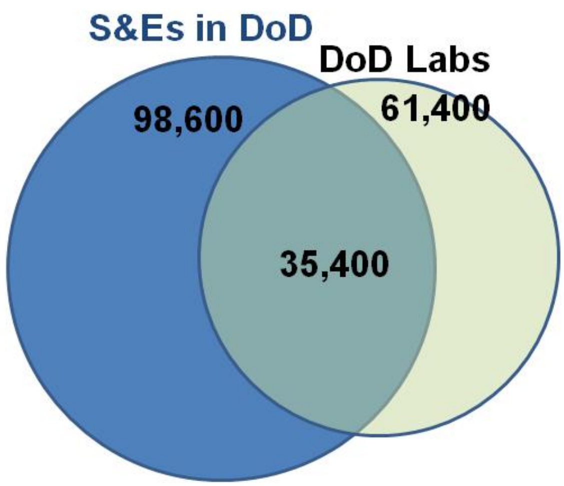

Figure A-1. Population of Interest: S&Es in DoD Labs (2008)

Note for Figure A-1: *Technicians and support personnel are not considered.*

A. DoD Labs

The list of DoD labs (see Table A-1) was compiled from the organizations in existence in 2008. These organizations evolved from the list defined in the *Department of*

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1 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

Table A-1. DoD Labs and Total S&Es Employed in 2008

DoD Lab	Number of S&Es
United States Air Force	
Air Force Research Laboratory (AFRL)	2,645
United States Army	
Army Research Laboratory (Adelphi, Maryland)*	1,261
Army Aviation and Missile Research Development and Engineering Center (AMRDEC) (Redstone Arsenal, Huntsville, Alabama)*	2,205
Armament Research, Development and Engineering Center (ARDEC) (Picatinny Arsenal, New Jersey)	2,250
Communications-Electronics Research, Development and Engineering Center (CERDEC) (Fort Monmouth, New Jersey)*	2,203
Tank-Automotive Research, Development and Engineering Center (TARDEC)	877
Simulation and Training Technology Center (STTC)	187
Army Research Institute for the Behavioral and Social Sciences (ARI)	31
Engineer Research and Development Center (ERDC)*	1,011
Army Material Systems Analysis Activity (AMSAA) Aberdeen Proving Ground (APG), Maryland	247
Natick Soldier Research Development and Engineering Center (RDEC)	368
Edgewood Chemical Biological Center	
U. S. Army Medical Research and Material Command (USAMRMC)*	327
U.S. Army Space and Missile Defense Command (USASMDC)	199
United States Navy	
Naval Research Laboratory (NRL) (Washington, D.C.)*	1,507
Naval Air Warfare Center (NAWC)	5,752
Naval Surface Warfare Center (NSWC)*	8,578
Naval Undersea Warfare Center (NUWC)*	2,515
Space and Naval Warfare Systems Centers (SSCs)	3,175
Naval Health Research Center (NHRC) (San Diego, California)	34
Naval Medical Research Center (NMRC) (Bethesda, Maryland)	24

Note for Table A-1: *An asterisk (*) following a lab name indicates participation in Lab Demo.*

Defense In-House S&T Activities FY2006: Management Analysis Report.[2] In addition, Navy Warfare Centers were added. Other organizations can be added easily into the pop-

2 Department of Defense. *Department of Defense In-House S&T Activities FY 2006: Management Analysis Report.* Prepared for the Office of the Secretary of Defense, Director, Defense Research and Engineering (The Pentagon, Washington, DC, July 2007). Available at http://www.dtic.mil/dtic/

ulation of interest, and the analyses can be iterated. Regardless, the current data sample is considered large enough to be representative of the DoD labs.

Furthermore, while some organizational changes have taken place in the last 20 years, the DoD lab organizations identified in 2008 (see Table A-1) are the basis of the historical population comparison.

B. S&E Occupations

As listed in Table A-2, S&Es are defined by 83 occupations, according to a commonly accepted Office and Personnel management (OPM) taxonomy, which has a direct correspondence to the occupational codes used by DoD. The National Science Foundation (NSF) also recognizes this definition of S&Es and uses the same basis in their compilation of federal statistics.

Table A-2. OPM-defined S&E Occupational Codes and Occupations

Code	Occupation	Code	Occupation	Code	Occupation
101	Social scientists, general	437	Horticulturalists	894	Welding engineers
106	Unemployment insurance specialists	440	Geneticists	896	Industrial engineers
110	Economists	454	Range conservationists	1140	Trade specialists
130	Foreign affairs analysts	457	Soil conservationists	1146	Agricultural market specialists
131	International relations specialists	470	Soil scientists	1147	Agricultural market analysts
132	Intelligence specialists	471	Agronomers	1301	Physical scientists, general
135	Foreign agricultural affairs analysts	482	Fishery biologists	1306	Health physicists
136	International cooperation specialists	486	Wildlife biologists	1310	Physicists
140	Manpower research analysts	487	Animal scientists	1313	Geophysicists
150	Geographers	801	Engineers, general	1315	Hydrologists
160	Civil rights analysts	803	Safety engineers	1320	Chemists
180	Psychologists	804	Fire prevention engineers	1321	Metallurgists
184	Sociologists	806	Materials engineers	1330	Astronomers and space scientists
190	General anthropologists	810	Civil engineers	1340	Meteorologists
193	Archeologists	819	Environmental engineers	1350	Geologists
334	Computer specialists	830	Mechanical engineers	1360	Oceanographers
401	Biological scientists, general	840	Nuclear engineers	1372	Geodesists
403	Microbiologists	850	Electrical engineers	1515	Operations research analysts
405	Pharmacologists	854	Computer engineers	1520	Mathematicians
406	Agricultural extension specialists	855	Electronics engineers	1529	Mathematical statisticians
408	Ecologists	858	Biomedical engineers	1530	Statisticians
410	Zoologists	861	Aerospace engineers	1540	Cryptographers
413	Physiologists	871	Naval architects	1541	Cryptography analysts
414	Entomologists	880	Mining engineers	1550	Computer scientists
415	Toxicologists	881	Petroleum engineers	1670	Equipment specialists
430	Botanists	890	Agricultural engineers	1730	Education research analysts
434	Plant pathologists	892	Ceramic engineers	2110	Transportation industry analysts
435	Plant physiologists	893	Chemical engineers		

C. DoD-Wide Scientists and Engineers

To provide context for the DoD lab S&Es, we should examine the breadth of S&Es across the entire DoD. Figure A-2 shows the Service composition of the 98,600 DoD S&Es. Figure A-3 shows the Service composition of the 35,400 DoD labs civilian S&E populations of interest and of the balance of 63,200 civilian S&Es located elsewhere in DoD. Besides the S&Es in the DoD labs, other S&Es are located at Major Range and Test Facility Bases (MRTFBs), at Operational Test Agencies (OTAs), and in the acquisition workforce.

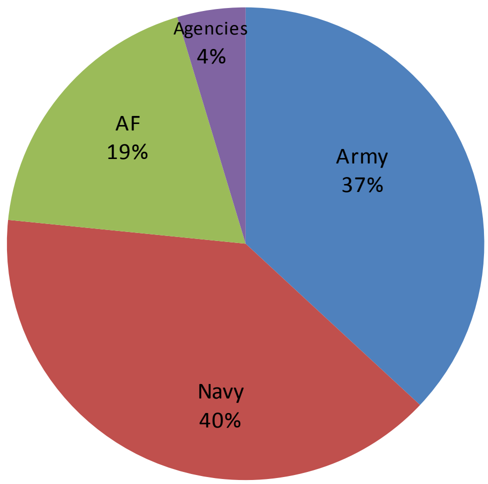


Figure A-2. Population of Interest: S&Es in DoD Labs in 2008

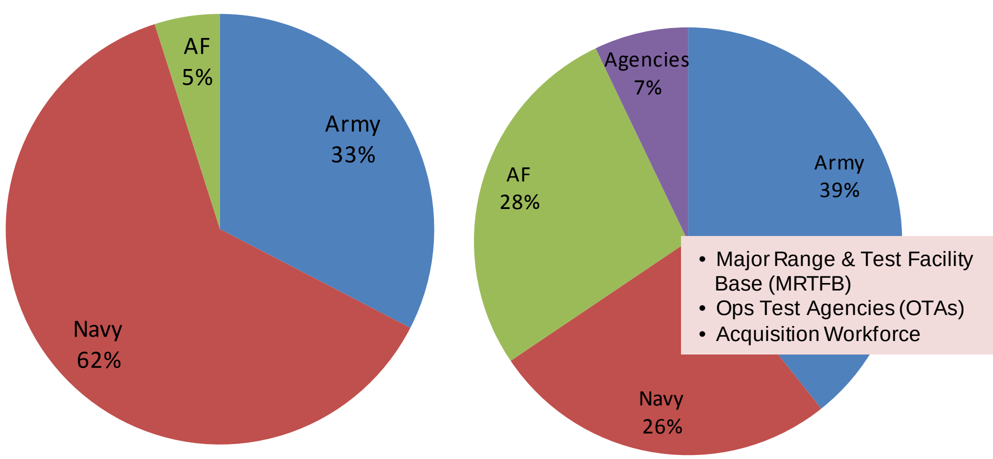


Figure A-3. Service Composition of S&Es in the DoD Labs and Those Elsewhere in DoD in 2008

D. Database Construction

The principal source of workforce data used in this study was the personnel database maintained by the DMDC, which provided IDA the files that captured S&E workforce data from the entire DoD civilian S&E workforce at 5-year intervals beginning in 1978 and going through 2008. The initial data set, generated by DMDC, selected all civilians who had an S&E occupation between 1978 and 2008. Once these individuals had been identified, a second data set used these IDs to search the DMDC records to discover whether their occupation had switched to a non-S&E job code during this 20-year time period. The second data set also indicated whether these people had left DoD entirely. The data files were then given to IDA and loaded into a Microsoft Access database.

The core tables of the IDA database hold the raw DMDC data—one table per year. Each core table has the same variable set (see Table A-3 for an alphabetical listing of key variables in the database), with the exception of some years during which data for a particular variable were not collected. Several small look-up tables were created to decode the different values that variables could take on. The core tables and the look-up tables were then combined to create a series of yearly analysis tables, which consisted of the core tables stripped down to include only variables that were useful to the analysis. The analysis tables were also down-selected to include only individuals who worked in S&E occupations and in the DoD labs as identified by their UIC. The yearly analysis tables were then queried directly in the database environment or exported to Excel for further analysis.

F. Reference Tables (in DMDC Database)

Table A-4 gives the race categories in the DMDC database. Table A-5 gives the handicap categories in the DMDC database.

Table A-3. Alphabetical Listing of Variables Received From DMDC

Variable Name	Field Number	Variable Name	Field Number
Agency Subelement Code	18	Handicap Type Code	10
Basic Pay Rate	78	Instructional Program Code	85
Appropriation Resource Identification Code	31	Major Occupation Group-Function Occupation Group Code	35
Army Service Career Program Code	77	Occupation Code	7
Civil Function Code	29	Occupational Category Code	37
DoD Occupation Group Code	84	Pay Plan Code	19
DoD Transfer Code		Pay Rate Determinant Code	11
Duty Location City Code	90	Person Age Quantity	34
Duty Location Country Code	88	Person Birth Calendar Date	6
Duty Location State Code	89	Person Identifier	1
Duty Location ZIP Identifier and Extension	94	Position Occupied Code	16
Education Level Code	24	Program Element Identifier	28
Education Level Effective Year Date	25	Race - Nation Origin Code	26
Federal Service Years Quantity	33	Retirement Eligibility Code	41
Frozen Service Years Quantity	63	Retirement Plan Code	15
Frozen Service Months Quantity	64	Step or Rate Identifier	21
Functional Area Code	36	Supervisory Code	23
Functional Classification Code	8	Unit Identifier	27
Gender		U.S. Citizenship Status Code	3
Grade, Level, Class, Rank, or Pay Band Identifier	20	Veterans Status Code	51

Source: DoD APF Civ Personnel Edit Unpacked File (200803 and After)–In Progress.

Table A-4. Race Categories in the DMDC Database

Prior to 2008	As of 2008
• Non-Hispanic Black	• American Indian or Alaskan Native
• Hispanic	• Asian or Pacific Islander not in Hawaii
• Non-Hispanic Puerto Rican	• Black, not of Hispanic origin
• Asian or Pacific Islander	• White, not of Hispanic origin
• White Non-Hispanic	• Not Hispanic in Puerto Rico
• American Indian or Alaskan Native	• Unknown/Not Applicable
	• Hispanic
	• Asian Indian in Hawaii
	• Chinese in Hawaii
	• Filipino in Hawaii
	• Guamanian in Hawaii
	• Hawaiian in Hawaii
	• Japanese in Hawaii
	• Korean in Hawaii
	• Samoan in Hawaii
	• Vietnamese in Hawaii
	• Other Asian or Pacific Islanders in Hawaii

Table A-5. Handicap Categories in DMDC Database

The following are targeted disabilities:

• 21 Total deafness in both ears, with understandable speech	• 66 Partial paralysis; both arms any part
• 23 Inability to read ordinary sixe print, not correctable by glasses	• 67 Partial paralysis; one side of the body including 1 arm and 1 leg
• 25 Blind in both eyes	• 68 Partial paralysis; three or more major parts of the body
• 26 Total deafness in both ears and unable to speak clearly	• 71 Complete paralysis; both hands
• 28 Missing extremities; one arm	• 72 Complete paralysis; one arm
• 32 Missing extremities; one leg	• 73 Complete paralysis; both arms
• 33 Missing extremities; both hands or arms	• 74 Complete paralysis; one leg
• 34 Missing extremities; both feet or legs	• 75 Complete paralysis; both legs
• 35 Missing extremities; one hand or arm and one foot or leg	• 76 Complete paralysis; lower half of body, including legs
• 36 Missing extremities; one hand or arm and both feet or legs	• 77 Complete paralysis; 1 side of body, including 1 arm and 1 leg
• 37 Missing extremities; both hands or arms and one foot or leg	• 78 Complete paralysis; three or more major parts of the body
• 38 Missing extremities; both hands or arms and both feet or legs	• 82 Other impairments; convulsive disorder
• 64 Partial paralysis; both hands	• 90 Other impairments; mental retardation
• 65 Partial paralysis; both legs any part	• 91 Other impairments; mental or emotional illness

Appendix B.
DoD Lab Director Interviews

A. Preparation for Lab Director Interviews

Table B-1 shows the background information provided to the lab directors in advance of the interviews.

Table B-1. Prep for Lab Directors

Human Capital Technical Assessment for the Department of Defense (DoD) Workforce of the Future

Background and Topics for Discussion (December 2008)

The Institute for Defense Analyses (IDA) was tasked by the Director, Research and Engineering (DDR&E) to analyze science and engineering (S&E) workforce trends in the DoD science and technology (S&T) laboratories. The objective of this study is to provide DDR&E an assessment of the current status of the S&E workforce employed at the DoD S&T labs and to present recommendations regarding the improvement of policies and practices for ensuring future DoD S&T lab workforce viability. The principal tasks include the following:

(1) Assess size and composition of current S&E workforce in DoD S&T laboratories
(2) Review projected trends in S&E workforce
(3) Identify anticipated future composition of S&E workforce for DoD
(4) Assess whether current S&E workforce programs, policies, and practices adequately address future DoD needs.

To date, the IDA study team has established a baseline description of the current S&E workforce in DoD S&T labs using data furnished by the Defense Manpower Data Center (DMDC). While these data provide important insights into the distribution of talent throughout the DoD laboratory system, it is important for us to get a better understanding of S&E workforce requirements from the lab directors themselves. We would like to know the following: *What do you see as current or anticipated S&E workforce needs? What DoD policies or practices facilitate your recruitment and retention of talented staff? What changes in those policies and practices would provide you with greater ability to meet those needs?*

We would be delighted if you would be available to meet with members of the IDA team to discuss some of the following topics:

- Organizational Design and Workforce Infrastructure
- Laboratory Research Resources
- Requirements/Recruitment/Retention/Retraining/Retirement Policies
- S&E Career Advancement Opportunity
- Near-Term and Longer Term S&E Workforce Needs.

The results of the interviews will be confidential and folded (without attribution or individual identification) into the general briefing we intend to present to DDR&E in January 2009. With your permission, however, we would like to include your name in a simple listing of those interviewed.

B. Interview Events

Interviews were scheduled with each Service and with a representative of basic research (BA1) and applied research (BA2/BA3). In summary, interviews were conducted with following lab directors and their staff:

- Dr. Eric W. Hendricks, Director of the Science, Technology, Experimentation, and Transition Division, Space and Naval Warfare Systems Command (SPAWAR) (12/10/08)
- Mr. John M. Miller, Director, Army Research Laboratory (ARL) (12/17/08)
- Dr. John A. Montgomery, Director of Research, Navy Research Laboratory (NRL) (12/22/08)
- Dr. Brendan B. Godfrey, Director, Air Force Office of Scientific Research (AFOSR) (12/23/08)
- Dr. A. Fenner Milton, Director, U.S. Army Night Vision and Electronic Sensors Directorate (NVESD) (12/30/08)
- Dr. Joseph A. Lannon, Technical Director, U.S. Army Armament Research, Development, and Engineering Center (ARDEC) (Video Teleconferencing (VTC) on 01/06/09))

Appendix C.
Cohort Analysis

A. Hiring Patterns

The Institute for Defense Analyses (IDA) evaluated the hiring patterns in Department of Defense (DoD) laboratories (DoD labs) at five points in time (1988, 1993, 1998, 2003, and 2008) by analyzing the fraction of "new" scientists and engineers (S&Es)[1] in each age cohort to calculate the fraction of "new hires." Results were grouped by age (under 30, 30–34, 35–39, 40–44, and 45–49) and by degree level (baccalaureate, masters, and PhD).

Among the 4,900 baccalaureate S&Es under the age of 30 who were employed by DoD labs in 2008, about 3,100 (64%) had been hired during the 5-year period ending in 2008. Of the 2,000 master's degree holders under the age of 30 employed in 2008, 727 (36%) had been hired during that 2003–2008 period. These data indicate that DoD lab directors actively recruited younger S&E staff in 2008, especially at the baccalaureate level. The next largest category of new hires in 2008 was the 30–34 age group at all degree levels.

Since "new hires" can be made at any age and/or degree level, IDA further analyzed the composition of the 2008 DoD lab S&E workforce relative to the share of workers in selected age categories and degree levels which represented individuals hired in the 5-year period preceding 2008. Findings are illustrated in Table C-1.

Table C-1. Fraction of the 2008 Civilian S&E Workforce Which Represented "New Hires" for Selected Age Cohorts, by Degree Level

Baccalaureate	Masters	PhD
69% for under age30	78% under age 30	90% under age 30
27% for age 30–34	44% for age 30–34	81% for age 30–34
22% for age 35–39	32% for age 35–39	35% for age 35–39
10% for age 40–45	13% for age 40–44	28% for age 40–44
6% for age 45–49	11% for age 45–49	18% for age 45–49

1 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

B. Retention Rates for New Hires

IDA analyzed retention patterns for DoD lab civilian S&Es at four points in time:

- Hired between 1983 and 1988 who left DoD by 1993
- Hired between 1988 and 1993 who left DoD by 1998
- Hired between 1993 and 1998 who left DoD by 2003
- Hired between 1998 and 2003 who left DoD by 2008.

The analyses were conducted for all S&Es, for scientists only, and for engineers only. The results were the same age cohorts as those appearing in Table C-1.

Findings indicate that retention rates for new hires under 30 years of age are lower than retention rates for any other age group included in the analysis:

- 74% for under 30 when hired
- 82% for those 30–34 when hired
- 88% for those 35–39 when hired
- 88% for those 40–44 when hired.

Furthermore, the retention rate for new hires under the age of 30 was substantially higher for workers who had been hired between 1983 and 1988 when analyzed in 1993. However, after 1993, the retention rate of these younger workers declined although improvement in the retention rate can be seen by 2008:

- 81% in 1993 (1983–1988 cohort)
- 70% in 1998 (1988–1993 cohort)
- 72% in 2003 (1993–1998 cohort)
- 74% in 2008 (1998–2003 cohort).

C. Overall Departure Rates

Rates of departure at DoD S&T Labs have varied over time. IDA analyzed departure rates at 5-year intervals using cross-sectional analysis of the personnel data files:

- Working in DoD S&T labs in 1988: 19% left by 1993
- Working in DoD S&T labs in 1993: 26% left by 1998
- Working in DoD S&T labs in 1998: 21% left by 2003
- Working in DoD S&T labs in 2003: 20% left by 2008.

Departure rates are generally higher for scientists than for engineers. IDA analyses revealed that 24% of the scientists working in DoD labs in 2003 had left the labs by 2008, in contrast to an 18% departure rate among engineers. Departure rates for these two groups are as follows:

- Working in DoD S&T labs in 1988: 21% scientists/18% engineers left by 1993
- Working in DoD S&T labs in 1993: 28% scientists/25% engineers left by 1998
- Working in DoD S&T labs in 1998: 25% scientists/20% engineers left by 2003
- Working in DoD S&T labs in 2003: 24% scientists/18% engineers left by 2008.

Among those workers over the age of 60, departure rates varied from a high of about 75% between 1993 and 1998 to a low of about 60% between 1998 and 2003, which is most likely driven by incentive programs. Rates of departures of civilian S&Es over the age of 60 and working in DoD S&T Labs in 2003 were as follows by 2008:

- 62% for those 60–64
- 64% for those 65–69
- 58% for those over 70.

Appendix D.
Race and Gender Composition of Scientists and Engineers (S&Es)[1] in DoD Labs and Across DoD

This appendix provides data that may be useful in future consideration of race and gender. We draw no conclusions from the data.

The data presented in the first two sections are from Service-reported data records within the Defense Manpower Data Center (DMDC) database.[2] The first two sections correspond specifically to Department of Defense (DoD) laboratories (DoD labs) and to all of DoD, respectively. For historical perspective, some of the 2008 results are compared to 1998 results to assess demographic trends. In the third section, National Science Foundation (NSF) statistics[3] for the entire U.S. S&E workforce are provided for perspective. The fourth section provides a brief summary.

A. Civilian Science and Engineering (S&E) Workforce in DoD Labs

Table D-1 compares the gender make-up of the 35,272 S&Es in the DoD labs in 2008 with the 31,949 S&Es in the DoD labs in 1998.

Table D-1. Gender Composition of Civilian S&E in DoD Labs in 1998 and 2008

Gender	2008	1998
Male	84.5%	86.2%
Female	15.5%	13.8%

1 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

2 Analyses using the DMDC database are also possible in terms of occupation, degree level, Service branch, age (or federal service years quantity), organizational location (e.g., state).

3 National Science Foundation, Division of Science Resources Statistics, *Women, Minorities, And Persons With Disabilities in Science and Engineering: 2009*. National Science Foundation Report NSF 09-305 (Arlington, VA; January 2009). Available at http://www.nsf.gov/statistics/wmpd/

Table D-2 shows the race composition by gender for 2008 compared to 1998 and indicates slightly more diversity among female workforce than the male workforce.

Table D-2. Race Composition of Civilian S&Es in DoD Labs in 1998 and 2008—for the Total Population and by Gender

	2008		
Ethnic Group	**Total**	**Male**	**Female**
White	80.2%	81.5%	73.4%
Asian	11.0%	10.6%	13.1%
Black	4.3%	3.5%	8.7%
Hispanic	4.0%	4.0%	4.3%
American Indian/Alaska Native	0.5%	0.5%	0.5%
Ethnic Group	**1998**		
White	83.2%	84.3%	76.8%
Asian	9.4%	9.2%	10.9%
Black	3.7%	3.0%	8.2%
Hispanic	3.3%	3.2%	3.7%
American Indian/Alaska Native	0.4%	0.4%	0.4%

Table D-3 shows the gender composition of each Service within the labs in 2008 and indicates that the Army has slightly more gender diversity than the DoD overall. The Air Force has the lowest fraction of female S&Es among DoD civilian lab S&Es.

Table D-3. Gender Composition of Civilian S&Es in DoD Labs in 2008—for the Total Population and by Service

Gender	Total	Army	Navy	Air Force
Male	84.5%	82.8%	85.0%	87.1%
Female	15.5%	17.2%	15.0%	12.9%

Figure D-1 shows the seniority levels by gender in 2008. Males are slightly more senior, but significantly more females are in the new hire cohort.

Table D-4 shows the education levels by gender in 2008. The distribution of educational attainment for men and women S&Es is similar.

Table D-5 shows the top S&E occupations in the DoD Labs by gender in 2008. The shaded areas in Table D-5 indicate notably higher percentages of females in specific occupations (relative to the 15.5% female overall average).

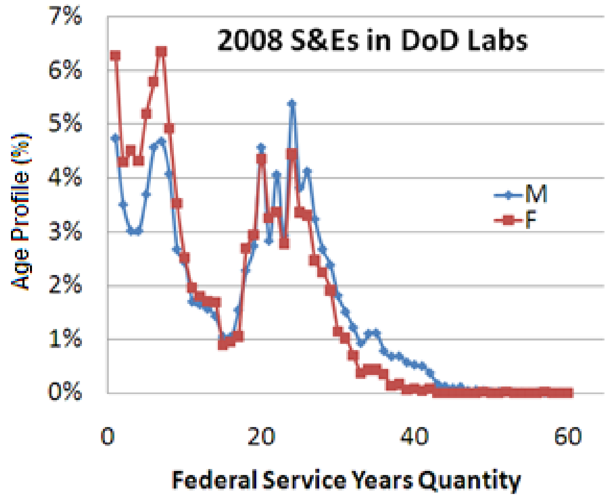


Figure D-1. Gender Seniority of Civilian S&E In DoD Labs in 2008

Table D-4. Education Levels of Civilian S&Es In DoD Labs in 2008—for the Total Population and by Gender

Educational Level	Total	Male	Female
Some HS	1.9%	1.8%	1.9%
HS Grad	0.5%	0.5%	0.7%
Bachelor's Degree	59.8%	59.5%	61.5%
Master's Degree	27.5%	27.5%	27.8%
Ph.D.	10.3%	10.7%	8.1%

Table D-5. Gender Mix of Top Civilian S&E Occupations in DoD Labs in 2008

Occupation	Population Size	Male	Female
Electronics Engineering	9,858	89.7%	10.3%
Mechanical Engineering	5,282	90.6%	9.4%
General Engineering	3,486	86.6%	13.4%
Computer Science	2,955	72.7%	27.3%
Computer Engineering	2,141	85.1%	14.9%
Aerospace Engineering	1,990	88.7%	11.3%
Physics	1,442	90.5%	9.5%
Electrical Engineering	982	88.5%	11.5%
Operations Research	866	68.2%	31.8%
Chemistry	743	73.8%	26.2%
Mathematics	643	59.9%	40.1%

Table D-5. Gender Mix of Top Civilian S&E Occupations in DoD Labs in 2008 (Continued)

Occupation	Population Size	Male	Female
General Physical Science	605	75.5%	24.5%
Chemical Engineering	602	71.9%	28.1%
Materials Engineering	570	81.9%	18.1%
Equipment Services	532	88.75	11.35
Industrial Engineering	323	67.2%	32.8%
Civil Engineering	309	85.8%	14.2%
Psychology	306	59.2%	40.8%
General Nat'l Resources Mgt and Biological Science	287	59.9%	40.1%
Naval Architecture	268	87.3%	12.7%
Microbiology	158	58.2%	41.8%

Table D-6 shows the gender mix within individual DoD Lab organizations in 2008. The shaded areas indicate notably higher percentages of females in specific organizations (relative to the 15.5% female overall average).

Table D-6. Gender Mix by DoD Lab Organization in 2008

DoD Lab Organizations	Population Size	Male	Female
Naval Surface Warfare Center (NSWC)	8,578	84.7%	15.3%
Naval Air Warfare Center (NAWC)	5,752	84.9%	15.1%
Space and Naval Warfare Systems Centers (SSCs)	3,175	84.6%	15.4%
Air Force Research Laboratory (AFRL)	2,645	87.0%	13.0%
Naval Undersea Warfare Center (NUWC)	2,515	85.7%	14.3%
Armament Research, Development and Engineering Center (ARDEC) (Picatinny Arsenal, New Jersey)	2,250	88.3%	11.7%
Army Aviation and Missile Research Development and Engineering Center (AMRDEC) (Redstone Arsenal, Huntsville, Alabama)	2,204	84.5%	15.5%
Communications-Electronics Research, Development and Engineering Center (CERDEC) (Fort Monmouth, New Jersey)	2,203	82.65	17.4%
Naval Research Laboratory (NRL) (Washington, D.C.)	1,507	87.3%	12.7%
Army Research Laboratory (ARL) (Adelphi, Maryland)	1,261	83.7%	16.3%
Engineer Research and Development Center (ERDC)	1,011	77.65	22.4%

Table D-6. Gender Mix by DoD Lab Organization in 2008 (Continued)

DoD Lab Organizations	Population Size	Male	Female
Tank-Automotive Research, Development and Engineering Center (TARDEC)	874	82.9%	17.1%
Natick Soldier Research, Development and Engineering Center (RDEC) Edgewood Chemical Biological Center	368	74.5%	25.5%
U. S. Army Medical Research and Material Command (USAMRMC)	327	67.9%	32.1%
Army Material Systems Analysis Activity (AMSAA) (Aberdeen Proving Ground (APG), Maryland))	247	78.9%	21.1%
U.S. Army Space and Missile Defense Command (USASMDC)	199	79.4%	20.6%
U. S. Army Simulation and Training Technology Center (STTC)	184	75.5%	24.5%
Naval Health Research Center (NHRC) (San Diego, California)	34	73.5%	26.5%
Army Research Institute for the Behavioral and Social Sciences (ARI)	31	77.4%	22.6%
Naval Medical Research Center (NMRC) (Bethesda, Maryland)	24	45.8%	44.2%
Grand Total	35,392	84.5%	15.5%

B. Civilian S&E Workforce Across the Entire DoD

For perspective on the DoD lab workforce, the statistics for S&Es throughout DoD were evaluated. The DoD workforce totaled 702,389 civilians in 2008 and has 98,616 civilian S&Es. This number includes non-degreed S&Es, who account for 12% of the total.

Table D-7 shows the race and gender composition of the DoD civilian S&E workforce in 2008. Note that there were 2 records of unknown gender and 71 records of unknown race (54 male; 17 female). Tables D-7 shows that 79.5% are white. The non-white composition includes 9% Asian and 12% of the historically underrepresented. The percent of women for all races except white is generally higher. The number of black and Hispanic males is nearly the same, but black females outnumber Hispanic females 2:1. Nearly one-third of the black S&Es are female.

DoD S&Es are predominantly engineers (62.25%). Table D-8 shows the gender composition of DoD S&Es: women are 17.83% of DoD S&Es, and, by professional field,

Table D-7. DoD Civilian S&E Race Mix in 2008—of Total Population and for each Gender

Ethnic Group	Total	Male	Female
White	79.47%	80.83%	73.19%
Asian	9.36%	9.19%	10.16%
Black	5.59%	4.58%	10.23%
Hispanic	4.44%	4.32%	4.98%
American Indian/Alaska Native	0.73%	0.70%	0.87%
Native Hawaiian/Pacific Islander	0.32%	0.29%	0.45%
Non-Hispanic	0.02%	0.02%	0.02%

12.64% of engineers are female and 26.38% of scientists are female. In fact, more DoD S&E women are scientists (55.86%) than engineers (44.14%), compared to male engineers (66.18%) and male scientists (33.82%).

Table D-8. Percentage of DoD Civilian S&Es by Gender in 2008—Total Population and by Field

Gender	Total	Engineer	Scientist
Male	82.17%	87.36%	73.62%
Female	17.83%	12.64%	26.38%

Tables D-9 shows the race composition of DoD S&Es. Nearly 12% of DoD engineers are Asian. There are a nearly equal number of black scientists and black engineers (2,700 of 98,600 DoD S&Es). While DoD S&Es are predominantly engineers (62%), Asians and Hispanics favor engineering even more so: 79% of Asians are engineers; 67% of Hispanics are engineers. Conversely, a higher percentage of blacks are in science, compared to all DoD S&Es: 50% of blacks are scientists. Blacks comprise 7.4% of DoD scientists.

Table D-9. Number of DoD Civilian S&Es by Race in 2008—Total Population and by Field

Race (Ethnic) Group	Total	Engineer	Scientist
White	78,370	61,342	37,201
Asian	9,232	7,273	1,959
Black	5,513	2,752	2,761
Hispanic	4,376	2,934	1,442
American Indian/Alaska Native	719	388	331
Native Hawaiian/Pacific Islander	317	189	128
Non-Hispanic	18	11	7
Total	98,545	74,889	43,829

Table D-10 addresses educational levels for each gender. The highest degree held by most S&Es is bachelors (56%), followed by masters (26%) and PhDs (6%). Slightly fewer women S&Es have PhDs (5.4%), compared to men S&Es (6.1%). Women account for 16.1% of DoD S&Es PhDs.

Table D-10. DoD S&E Education Levels for Each Gender in 2008

Educational Level	Total	Male	Female
Some HS	**9.4%**	9.5%	9.0%
HS Grad	**2.4%**	2.3%	2.6%
Bachelors Degree	**55.7%**	56.1%	54.1%
Masters Degree	**26.4%**	25.9%	28.9%
Ph.D.	**6.0%**	6.1%	5.4%

Table D-11 shows the racial mix per educational level. Ethnic minorities make up a total of 4.6% of PhDs in the DoD.

Table D-11. DoD S&E Education Levels by Race and Gender

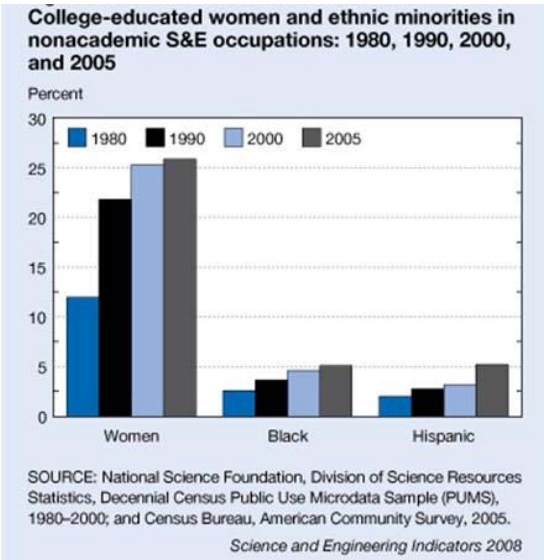
	Some HS			HS Graduate			Bachelors			Masters			PhDs			
Ethnic Group	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**Grand Total**
White	81.6	76.9	80.8	78.2	74.9	77.6	79.7	71.2	78.2	82.8	74.6	81.2	83.2	79.7	82.6	79.5
Asian	3.1	4.2	3.3	3.8	5.3	4.1	10.3	11.8	10.6	8.7	9.0	8.7	12.8	13.0	12.8	9.4
Black	8.9	11.0	9.3	9.9	11.0	10.1	4.3	10.3	5.3	3.9	11.0	5.3	1.8	3.7	2.1	5.6
Hispanic	5.1	6.6	5.3	6.1	6.4	6.2	4.7	5.4	4.8	3.8	4.0	3.8	1.7	2.6	1.8	4.4
American Indian/ Alaska Native	1.0	0.9	0.9	1.5	1.1	1.5	0.7	0.8	0.7	0.6	1.0	0.7	0.6	0.8	0.6	0.7
Native Hawaiian/ Pacific Islander	0.3	0.4	0.4	0.4	1.3	0.6	0.3	0.5	0.4	0.3	0.4	0.3	0.0	0.1	0.1	0.3
Non-Hispanic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note for Table D-11: *All numbers are percentages.*

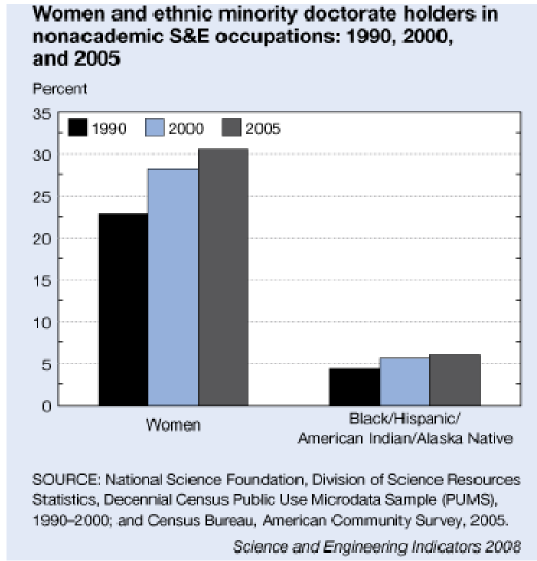
C. U.S. S&E Workforce

For comparison with the DoD labs and DoD as a whole, the NSF provides trend data on race and gender of the U.S. S&E workforce as a whole. Key highlights from the NSF Science and Engineering Indicators are that the ethnic minorities in S&E occupations remain fewer in number relative to the total college-educated workforce. Women comprise 25.8% of S&E occupations compared to 47.2% of the total college-educated workforce, and women hold 30.6% of S&E PhDs compared to 34.1% women PhDs in the total labor force. Black and Hispanic each comprise 5% of the S&E occupations. Ethnic minorities together are 5% of PhDs.

Figure D-2a shows the increasing percentage of women and ethnic minorities over 25 years between 1980 and 2005. The share of minorities in S&E occupations nearly doubled between 1980 and 2005. Figure D-2b shows the increasing percentage of women and ethnic minority doctorate holders over 15 years between 1990 and 2005.



(a)



(b)

Figure D-2. Gender and Race Trends in the U.S. S&E Workforce

D. Summary

Approximately 98,600 (14%) of DoD personnel are in S&E occupations. The number of DoD civilian S&E women (18,000 (18%)) is less than the national S&E average (women comprise 25.8% of U.S. S&E occupations). The minority representation is similar compared to the national average: 79% white; 9% Asian; 11% underrepresented minorities (i.e., 5.6% black; 4.4% Hispanic). Black and Hispanic each are about 5% of U.S. S&E occupations.

Women DoD S&Es hold fewer PhDs than the national average S&E PhDs. Women account for 18% of DoD S&E PhDs but represent 30.6% of U.S. non-academic S&E PhDs. The minority representation at DoD S&E and national PhD levels is the same. Ethnic minorities account for 5% of DoD S&E PhDs and 5% of U.S. S&E PhDs.

Male civilian S&Es in DoD are slightly older and have slightly more tenure. The average age of a male civilian S&Es in DoD is 46 years and the average government experience is 17 years. The average age of female civilian S&Es in DoD is 42 years, and the average government experience is 14 years.

Appendix E.
U.S. Science and Engineering (S&E) Degree Awards to U.S. Citizens and to Temporary Residents

The data in this appendix are derived from the data tables provided by the National Science Foundation (NSF).[1]

A. U.S. Citizens

Figure E-1 shows, by degree level, the overall historical trend in science degrees awarded in the United States to U.S. citizens.

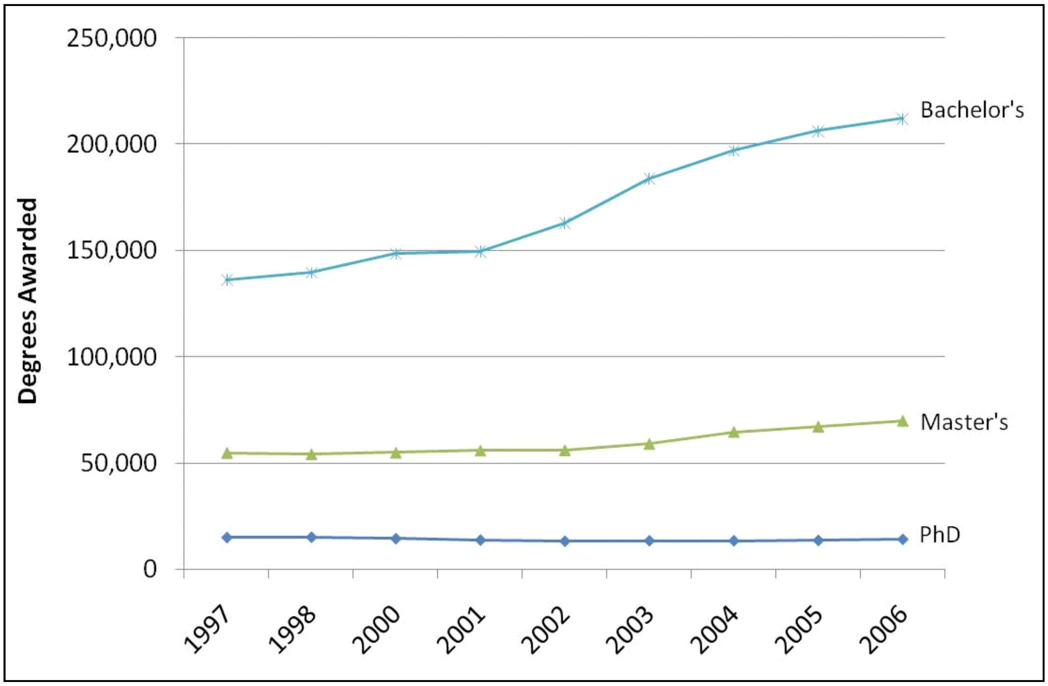


Figure E-1. Degrees in Science for U.S. Citizens and Permanent Resident by Degree Type, 1997–2006

Figures E-2, E-3, and E-4 show the degree production by discipline for each of the three degree levels.

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1 National Science Board. *Digest of Key Science and Engineering Indicators 2008* National Science Board report NSB-08-2 (Arlington, VA: National Science Foundation, 2008). Available at http://www.nber.org/~sewp/SEWPdigestFeb08/nationalscienceboardindicators.pdf

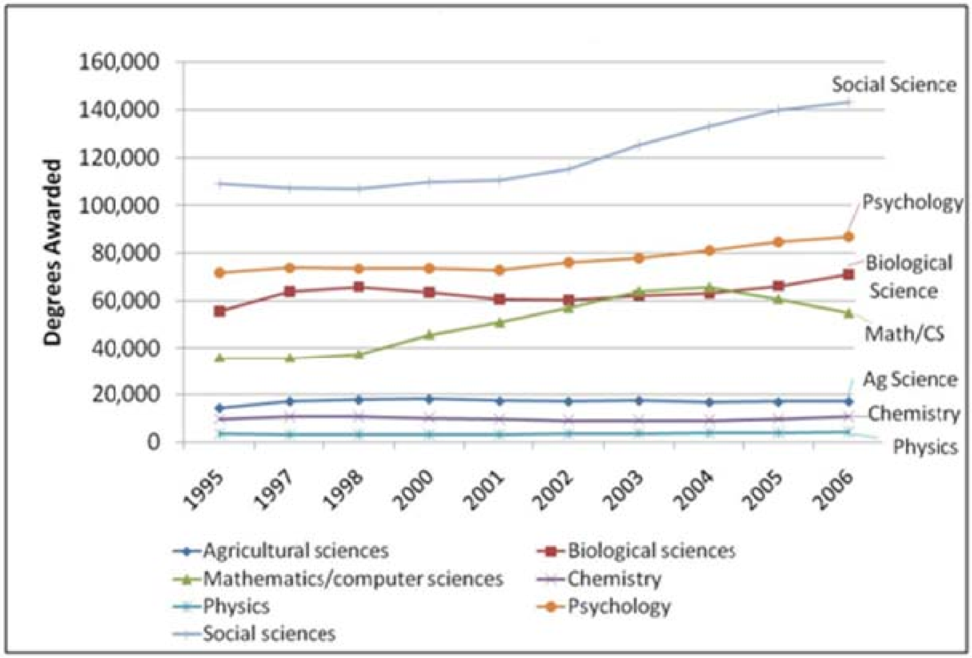

Figure E-2. Bachelor's Degrees Awarded to U.S. Citizens and Permanent Residents by Field of Science, 1995–2006

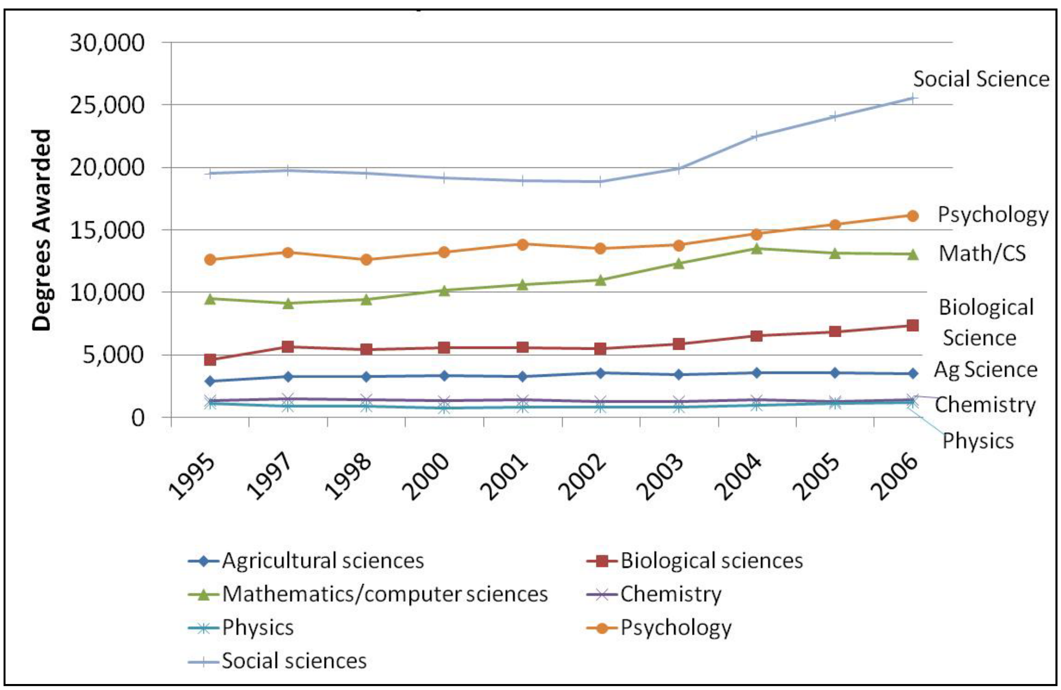

Figure E-3. Master's Degrees Awarded to U.S. Citizens and Permanent Residents by Field of Science, 1995–2006

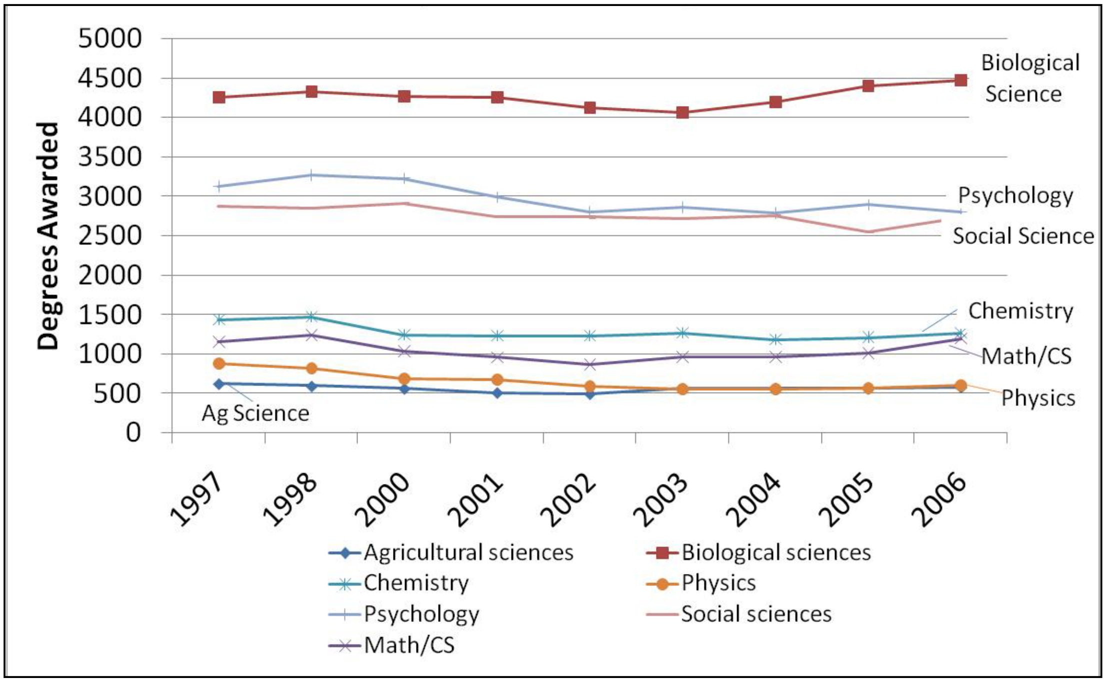

Figure E-4. Doctorates Awarded to U.S. Citizens and Permanent Residents by Field of Science, 1997–2006

Figure E-5 shows, by degree level, the historical trend in engineering degrees awarded in the United States to U.S. citizens.

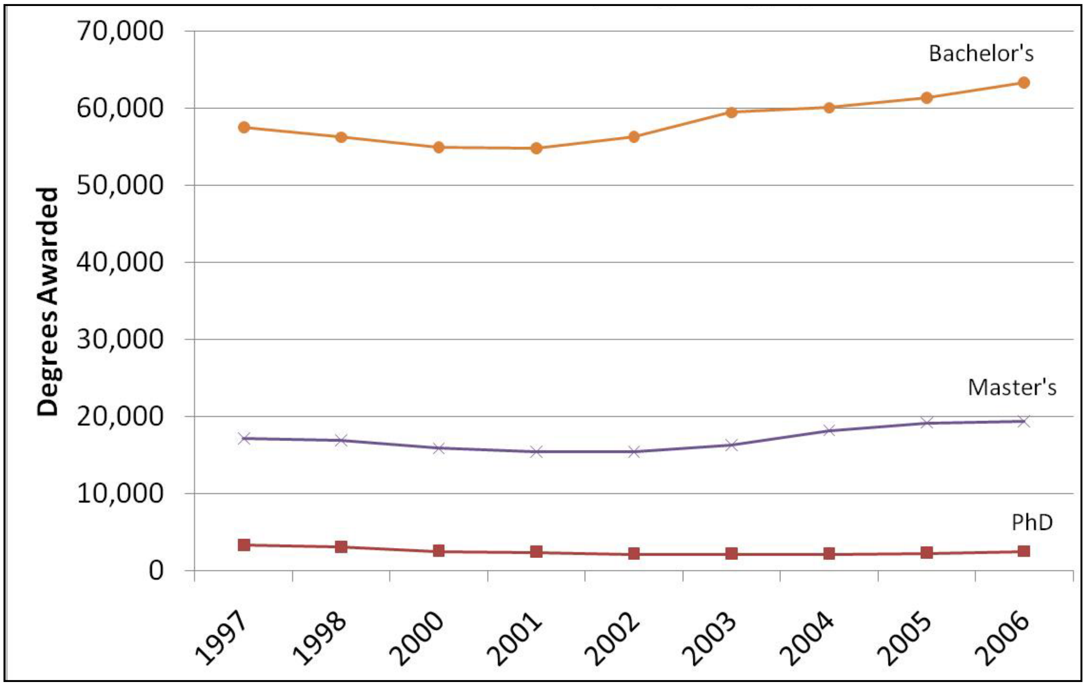

Figure E-5. Degrees in Engineering for U.S. Citizens and Permanent Resident by Degree Type, 1997–2006

Figures E-6, E-7, and E-8 show the degree production by discipline for each of the three degree levels.

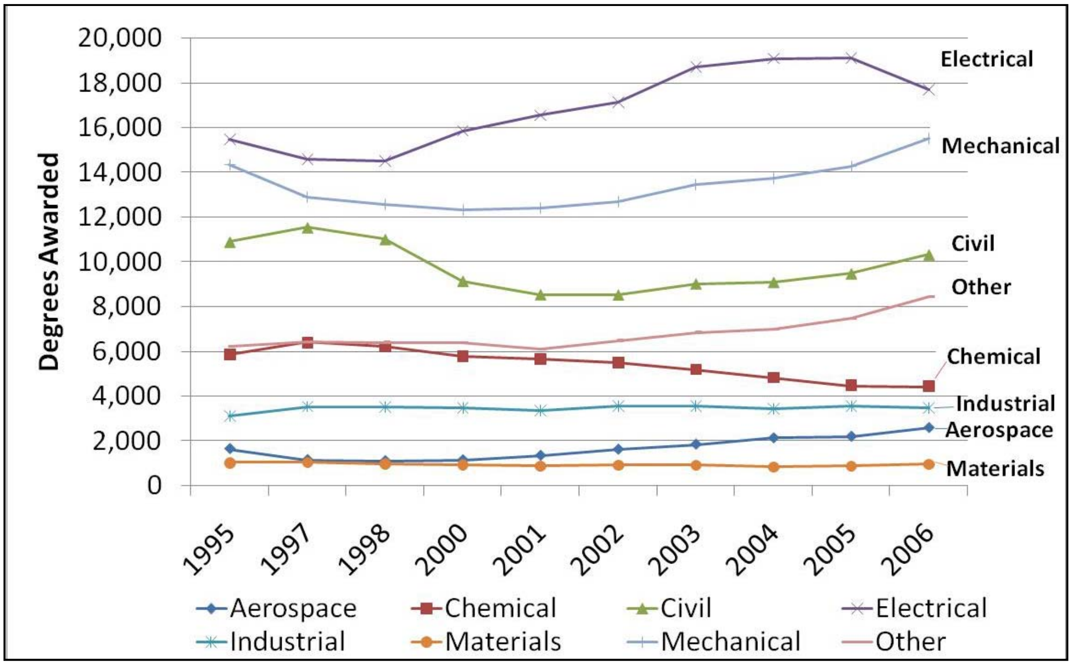

Figure E-6. Bachelor's Degrees Awarded to U.S. Citizens and Permanent Residents by Field of Engineering, 1995–2006

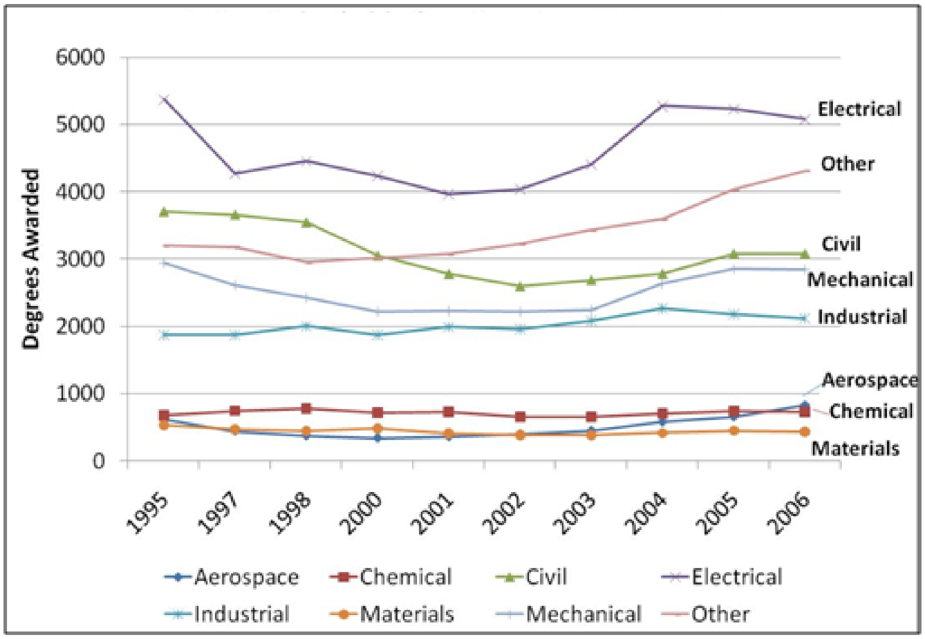

Figure E-7. Master's Degrees Awarded to U.S. Citizens and Permanent Residents by Field of Engineering, 1995–2006

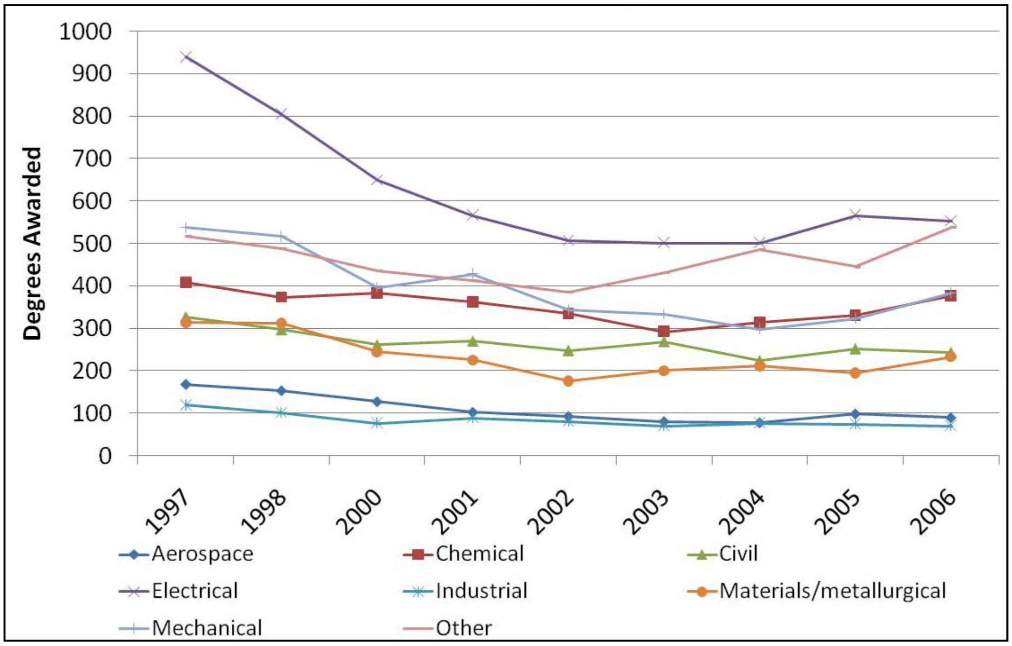

Figure E-8. Doctorates Awarded to U.S. Citizens and Permanent Residents by Field of Engineering, 1997–2006

B. Temporary Residents

Figure E-9 shows, by degree level, the historical trend in science degrees awarded in the United States to temporary residents. For comparison, Figure E-10 shows the percentage of science degrees awarded to temporary residents.

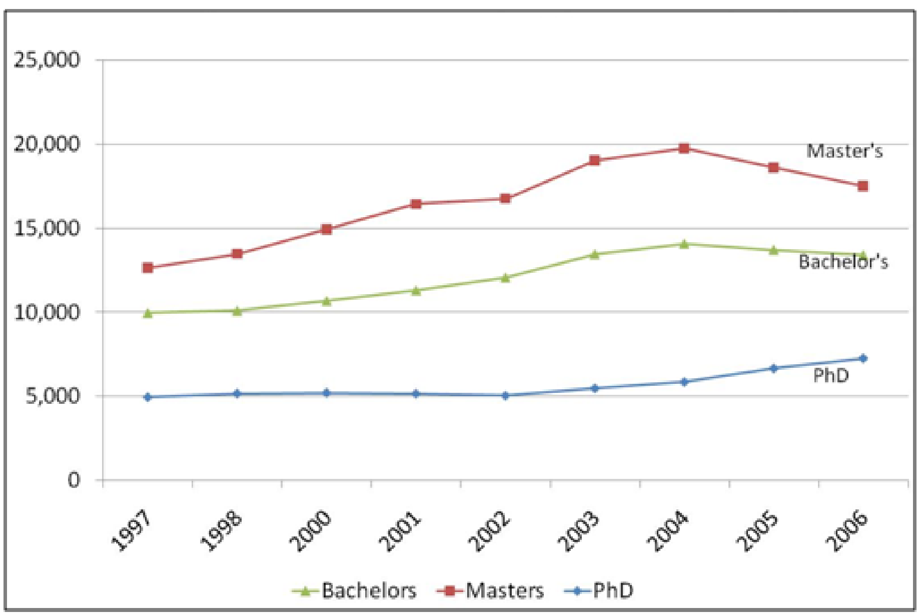

Figure E-9. Degrees in Science for Temporary Residents by Degree Type, 1997–2006

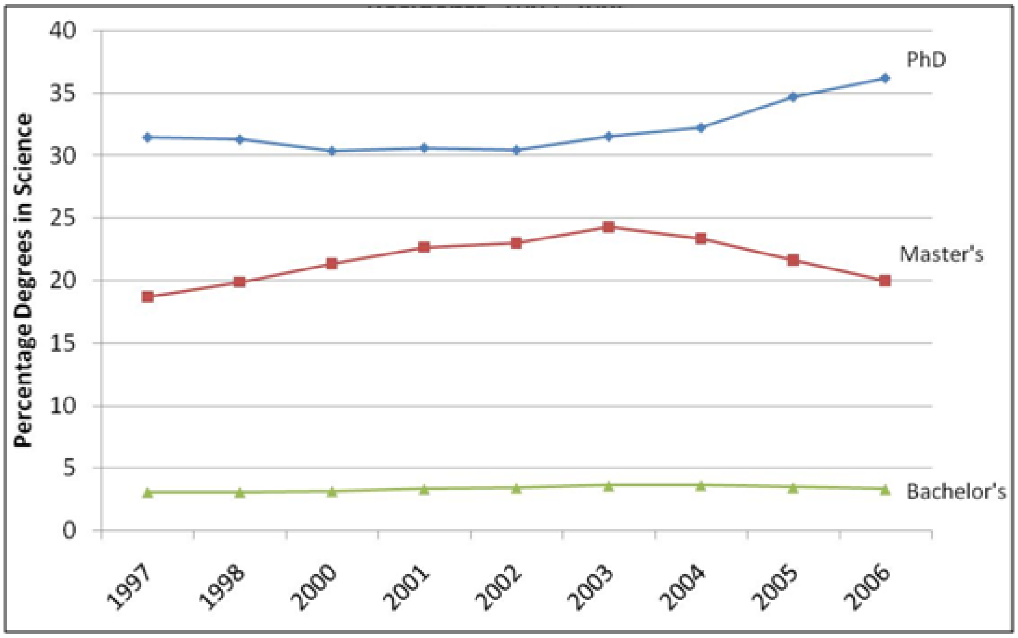

Figure E-10. Percentage of Degrees in Science Awarded to Temporary Residents by Degree Type, 1997–2006

Figures E-11, E-12, and E-13 show the degree production by discipline for each of the three degree levels.

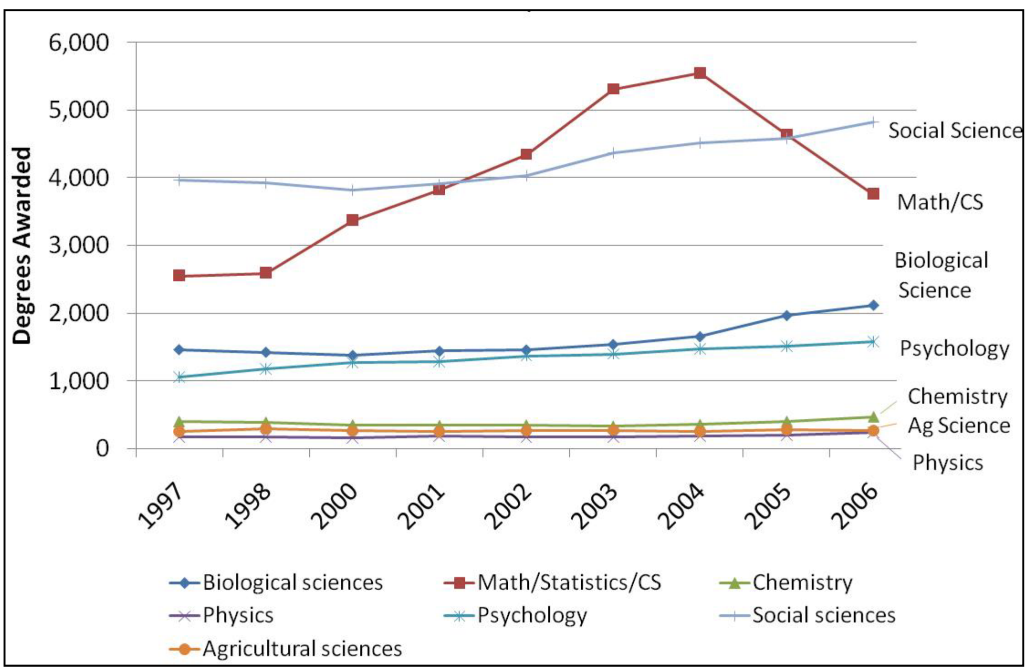

Figure E-11. Bachelor's Degrees Awarded to Temporary Residents by Field of Science, 1995–2006

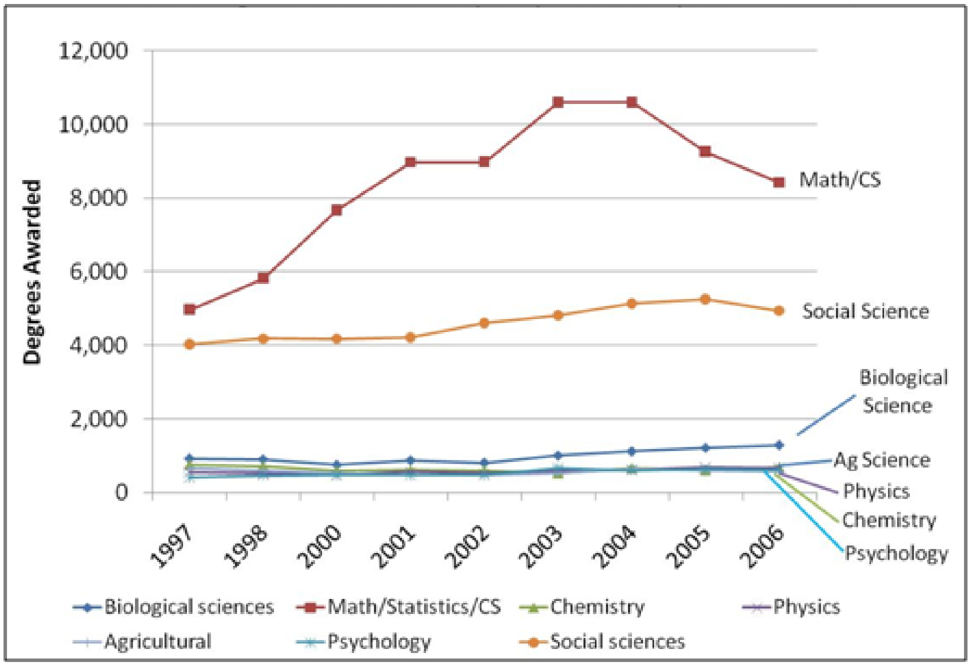

Figure E-12. Master's Degrees Awarded to Temporary Residents by Field of Science, 1995–2006

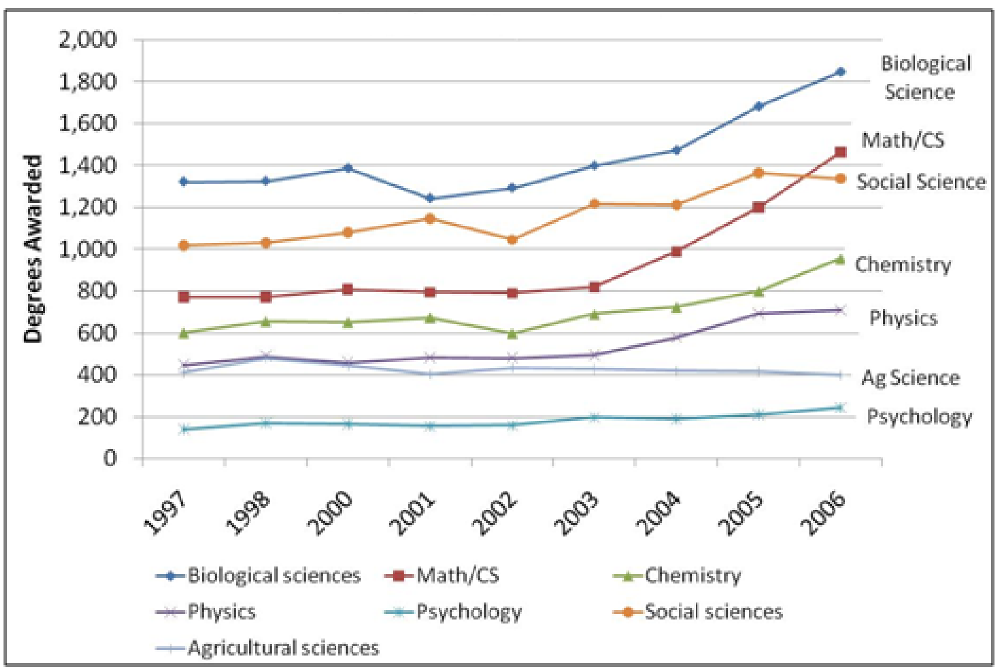

Figure E-13. Doctorates Awarded to Temporary Residents by Field of Science, 1997–2006

Figure E-14 shows, by degree level, the historical trend in engineering degrees awarded in the United States to temporary residents. For comparison, Figure E-15 shows the percentage of degrees awarded to temporary residents.

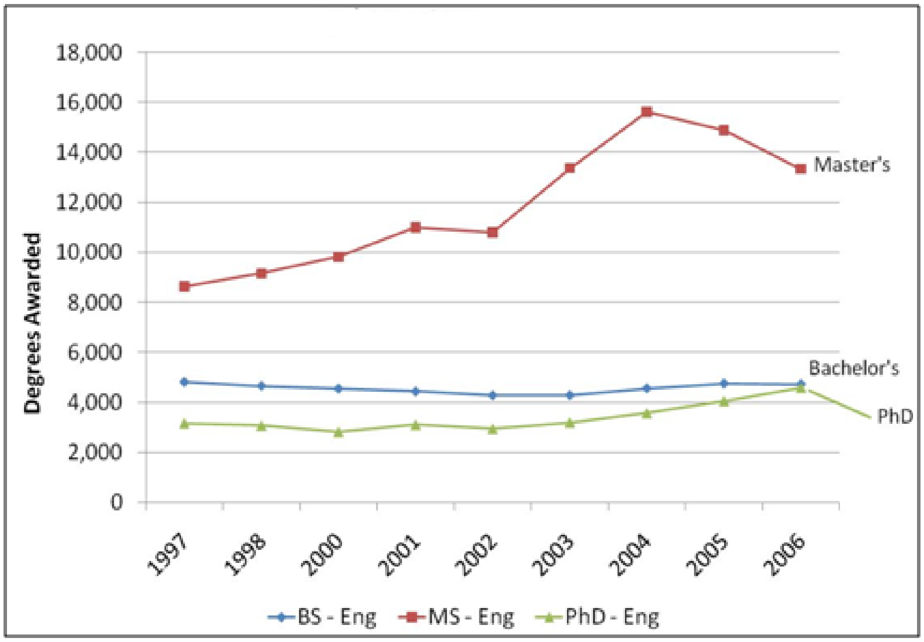

Figure E-14. Degrees in Engineering for Temporary Residents by Degree Type, 1997–2006

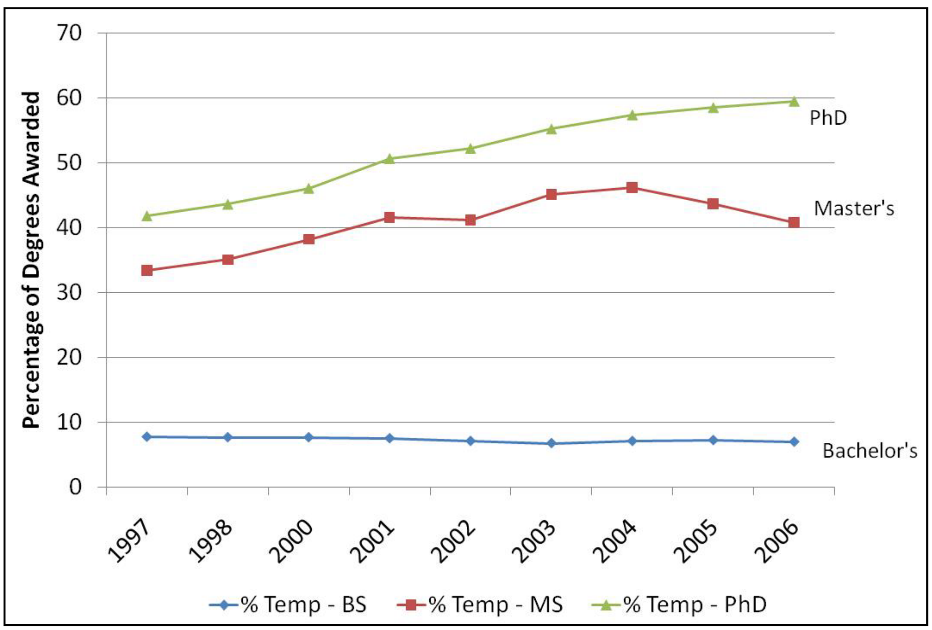

Figure E-15. Degrees in Engineering for Temporary Residents by Degree Type, 1997–2006

Figures E-16, E-17, and E-18 show the degree production by discipline for each of the three degree levels.

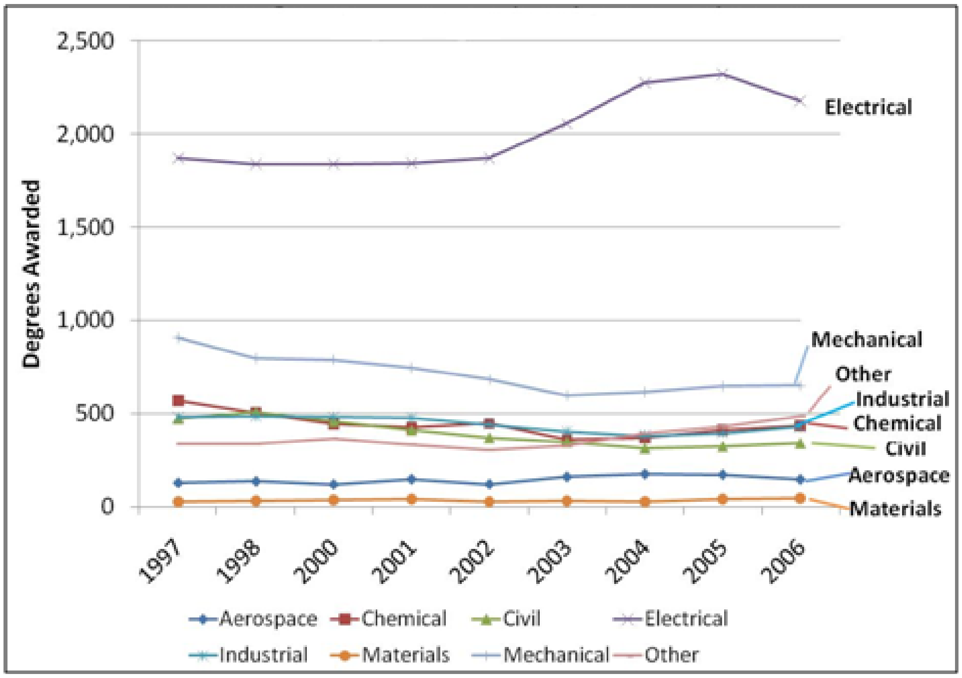

Figure E-16. Bachelor's Degrees Awarded to Temporary Residents by field of Engineering, 1995–2006

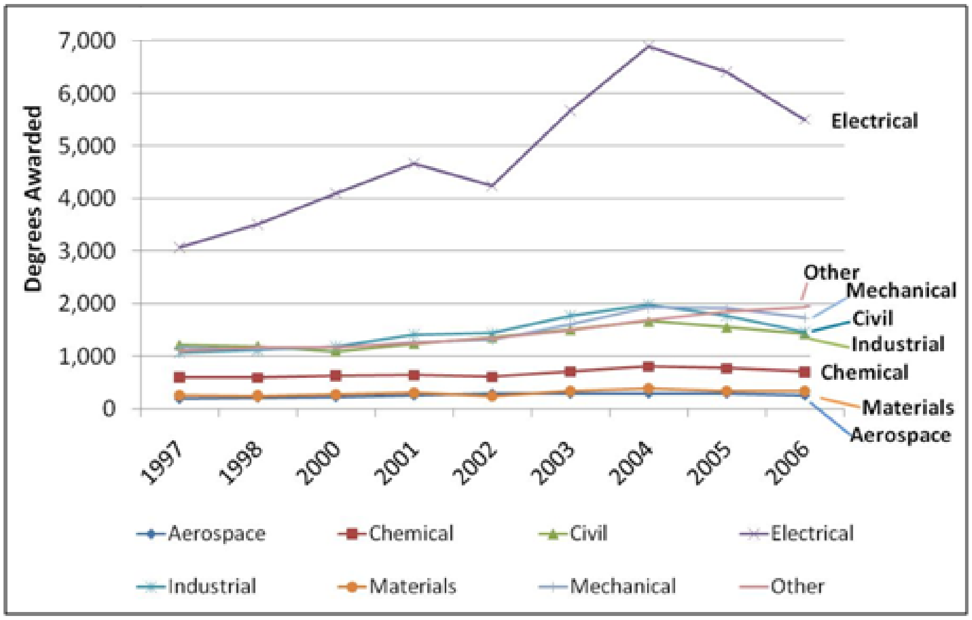

Figure E-17. Master's Degrees Awarded to Temporary Residents by Field of Engineering, 1995–2006

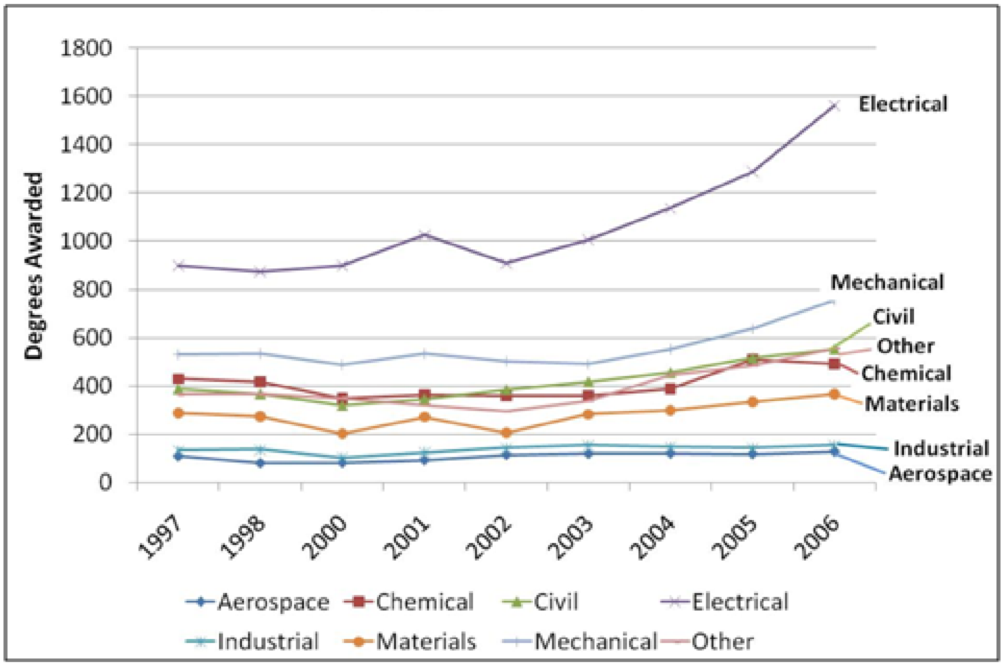

Figure E-18. Doctorates Awarded to Temporary Residents by Field of Engineering, 1997–2006

Appendix F.
Literature Highlights

This appendix summarizes the highlights from a selected set of contemporary S&E workforce studies examined for this study.

A. Scientists and Engineers (S&Es)[1] in DoD Laboratories

1. Institute for Defense Analyses (IDA) Paper

An IDA study by John Metzko and Jesse Orlansky[2] collected information on 25,000 civilian S&Es employed in 66 Department of Defense (DoD) laboratories (DoD labs) in 1986. Their approach focused on "recruitment" and "retention." The authors sent survey questionnaires to 66 labs (35 Army, 20 Navy, and 11 Air Force) and used the Defense Manpower Data Center (DMDC) database. They also analyzed "pay comparability" using a variety of federal and non-federal data sources (chiefly professional association salary surveys).

The general findings were that the civilian science and engineering (S&E) lab workforce grew between 1981 and 1986, largely in engineering. Physical scientists and mathematicians made up 70% of lab workforce in 1986, which was a significantly higher fraction than that of the national S&E workforce. Electronics and electrical engineering accounted for 65% of the 1986 lab engineering workforce, which was also a higher percentage than that of the national engineering workforce. Growth in proportion of S&E degrees awarded to non-U.S. citizens reflected a shrinking pool of available talent. Lab directors reported that pay (low salaries) and benefits were the chief obstacles in recruiting and retaining civilian S&Es.

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1 Throughout this report, S&E is used as an acronym for "science and engineering" and "scientist and engineer." When used in the plural form for the latter, it will appear as S&Es.

2 Metzko, John, and Jesse Orlansky. *Study II of Scientists and Engineers in the DoD Laboratories*. IDA Paper P-2589 (Alexandria, VA: Institute for Defense Analyses, 1990).

2. Naval Research Advisory Committee (NRAC) Report

NRAC assembled a panel including representatives from NRAC, the Army Science Board (ASB), and Air Force Scientific Advisory Board (SAB) to assess the DoD labs. Their approach was to review past studies and conduct fact-finding meetings. An NRAC report was published in May 2002.[3]

The general observations of this panel were that the role of DoD labs is essential and critical. A characteristic of world-class labs is the highest quality S&Es. The authors observed that few recommendations from previous DoD lab studies had been implemented. Congress recognized the problem and tried to help. Immediate action and sustained commitment from the Office of the Secretary of Defense (OSD) and Service leaders was recommended. Further inaction "would be irresponsible" (p. 3).

3. RAND Report

A 2003 RAND report[4] reviewed testimony before U.S. Senate Committee on Governmental Affairs and summarized RAND's research.

The approach was to discuss the use of the "tools" that were available to DoD to shape the retirement behavior of civilian workforce (e.g., Voluntary Separation Incentive Programs (VSIPs) or buyouts, Voluntary Early Retirement Authority (VERA), and retention allowances)). The general observations were that workforce-shaping tools could have a significant effect on retirement behavior,[5] based on DoD civilian employees 50 or older who participated in the Civil Service Retirement System (CSRS) and on the large effect of retention allowances. The authority for flexibility-related tools is limited. The Office of Personnel Management (OPM) estimated that retention allowances were given to less than 1% of Executive Branch employees, including DoD, in 1998. Some aspects

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3 Bachkosky, J. M., J. B. Erickson,.J. E. Grant, G. V. Herrera, J. A. Johnson, N. Kobitz, D. L. Lamberson, J. R. Luyten, M. R. O"Neill, I. C. Peden, E. K. Reedy, R. C. Spindel, and M. A. Wartell. *Science and Technology, Community in Crisis*. Naval Research Advisory Committee Report NRAC 02-03 (Arlington, VA: Naval Research Advisory Committee, . May 2002). Available at http://www.onr.navy.mil/nrac/docs/2002_rpt_st_community_crisis.pdf

4 Asch, B. J. *The Defense Civilian Workforce: Insights From Research.* RAND Report CT-208 (Santa Monica, CA: RAND, May 2003). Available at http://www.rand.org/pubs/testimonies/2005/CT208.pdf

5 Asch, B. J., S. Haider, and J. Zissimopoulous. *The Effects of Workforce-Shaping Incentives on Civil Service Retirements: Evidence From the Department of Defense.* RAND Documented Briefing (Santa Monica, CA: RAND, 2003). Available at http://www.rand.org/pubs/documented_briefings/2005/DB404.pdf

of the Civil Service System are rigid (e.g., pay service) and cumbersome. In addition, workforce challenges facing DoD arise from decisions to downsize by hiring fewer workers. Effecting meaningful change will require the following:

> To ensure a high performing civilian workforce, the leadership in the DoD and Congress must demonstrate a strong and ongoing commitment to not only identify but also reform inappropriate processes and policies that hinder the effectiveness of the civilian workforce in meeting its current and future missions (p.13).[6]

4. Government Accountability Office (GAO) Report

The GAO issued a report[7] in June 2004 to the Ranking Minority Member, Subcommittee on Readiness, Committee on Armed Services, U.S. House of Representatives. GAO was asked to address DoD's efforts to strategically plan for its future civilian workforce at the Operational Support Command (OSC), the military Services' headquarters, and the Defense Logistics Agency (DLA). The report was based on a review of administrative files and interviews of selected officials. The work took place from April 2003 through June 2004.

The general findings were that the DoD's downsizing in the 1990s did not focus on strategically shaping its civilian workforce. OSD and others have taken steps to develop and implement civilian strategic workforce plans. These plans generally lack some key elements. For example,

- None of the plans included gap analyses. Accordingly, strategies to hire, develop, and retain best possible workforce must be addressed.
- None of the plans included results-oriented performance measures to provide data to assess the outcomes of civilian human capital initiatives.

DoD's major challenge is to develop tools to collect/store and manage data on workforce competencies.

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6 Asch, B. J. *The Defense Civilian Workforce: Insights From Research.* RAND Report CT-208 (Santa Monica, CA: RAND May 2003). Available at http://www.rand.org/pubs/testimonies/2005/CT208.pdf

7 Government Accountability Office (GAO). *DoD Civilian Personnel: Comprehensive Strategic Workforce Plans Needed.* GAO Report GAO-04-753 (Washington, DC: Government Accountability Office, June 2004). Available at http://www.gao.gov/new.items/d04753.pdf

5. OPM Report

The U.S. OPM issued a report in December 2006[8] on the Status of the Personnel Demonstration Projects in the federal government. The report included an analysis of the DoD S&T Reinvention Laboratory Demonstration (Lab Demo) program authorized in 1995 (P.L. 103-337). Key features of Lab Demo included

- Simplified job classification
- Pay-banding
- Pay-for-performance or contribution-based pay
- Enhanced recruitment and staffing
- Enhanced training and development
- Modified reduction in force.

Information summarized in this report comes "largely from evaluations of currently active demonstration projects," including:

- Summative evaluation 2002
- Interim results 2004–2005
- Pulse survey 2005
- Agency survey data for 2003–2005.

The report's general observations are that the purpose of Lab Demo is to improve the effectiveness of DoD labs through "a more flexible and responsive personnel system." Findings indicate improved "results-oriented" performance, based on a proportion of staff who agree that pay is linked to performance. In addition, the ability to recruit and retain a high-quality workforce increased, resulting in positive impact on job satisfaction. Pay-banding enabled Lab Demos to offer higher, more competitive starting salaries than possible under the General Schedule (GS) system. Managers are more satisfied with the competence of newly hired S&Es. In summary, personnel processes improved, based on focus group input.

6. National Defense University (NDU) Report

A July 2008 essay by NDU professor and former Naval Research Laboratory (NRL) Director of Research, T. Coffey, focuses on "Building the S&E Workforce for

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8 U.S. Office of Personnel Management. *A Status Report on Personnel Demonstration Projects in the Federal Government* (Washington, DC: OPM, December 2006).

2040: Challenges Facing the Department of Defense”[9]. The author describes the historical trends in DoD programs since the 1920s, DoD workforce trends, and a “simple strategy” for the DoD S&E workforce. He also makes projections about the 2040 S&E workforce.

The general observations are that the DoD’s civilian S&E workforce continues to decline relative to national workforce and could reach a point where the DoD lab workforce is “irrelevant.” The author suggests a method of addressing this concern by establishing a floor for the average defense program when measured relative to gross domestic product (GDP). The aim is to maintain a fixed percentage of the national S&E workforce at DoD labs. The author offers several scenarios for managing the DoD lab workforce over the next 30 years.

7. IDA Central Research Project (CRP)

A 2008 IDA CRP by George C. Tolis[10] describes “An Approach to Determining the Probability of Retirement Among ‘Retirement Eligible’ Workers”. The author’s approach was to examine retirement patterns among civilian DoD workers. The analysis included optional “regular” retirement but not “early” retirement. The minimum retirement age: 55 to 57 based on year of birth.

The report findings are that one-third of those eligible to retire are still likely to be on the job after 6 years. In addition, the S&E rate of retirement is less than DoD average. Specifically, the probability of retirement is as follows:

- 24% within first year of eligibility
- Another 11% within 2 years
- A total of 67% within 6 years of eligibility

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9 Coffey, T. *Building the S&E Workforce for 2040: Challenges Facing the Department of Defense* (Washington, D.C.: National Defense University, Center for Technology and National Security Policy, July 2008). Available at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA485441&Location=U2&doc=GetTRDoc.pdf

10 Tolis, George C. *An Approach to Determining the Probability of Retirement Among “Retirement Eligible” Workers.* IDA Central Research Project C-7064 (Alexandria, VA: Institute for Defense Analyses, 2008).

B. Trends in the U.S. S&E Workforce

1. NAS Report: Rising Above the Gathering Storm

A 2005 National Academy of Sciences (NAS) report[11] was completed in only 10 weeks. This report was conceived as a "wake-up" call for the nation and warned that the United States could rapidly lose its edge in science and technology (S&T) innovation to economic competitors, thus degrading America's standard of living, employment opportunities, and national security. The idea emanating from the report crystallized in Congress with the publication of *The World is Flat* by Thomas Friedman (2005).[12]

Some analysts have argued that the fast pace of the NAS study led to lapses in logic. David Guston (Arizona State University) observes that the NAS report "follows a long series of reports from the science community asking for more and more, with no other plan to get more. Doubling the number of scientists and engineers is not a policy. What counts is whether we are training the right type of scientists and engineers."[13] David Hart (George Mason University) says that "the math and science only represent a part of what we need. If we focus all our attention there, we're going to miss the interesting things that go on at the intersection of technology on one hand and arts and design on the other. I worry that the report might reinforce teaching to the test instead of encouraging more creative inquiry."[20] Gary Gereffi (Duke University) "questions whether developing countries even have an advantage of numbers."[20]

2. NSF Science and Engineering Indicators 2008

The National Science Board in January 2008 issued an updated report on Science and Engineering Indicators. Chapter 3 of Volume 1 addresses the U.S. S&E labor force.

The report indicates that the S&E workforce in the United States has grown rapidly for decades: from fewer than 200,000 in 1950 to over 4.8 million in 2000. S&E occupations have generally recovered from unusually high unemployment in the most recent recession; unemployment among S&E occupations declined to 1.6% in 2006,

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11 National Academy of Sciences (NAS). *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academies Press, 2005). Available at http://books.nap.edu/openbook.php?record_id=11463&page=R1

12 Friedman, T. *The World Is Flat* (New York: Farrar, Straus & Giroux, April 2005).

13 Brown, Alan S. "The Gathering Storm: Can the U.S. Preserve Its Lead in Science & Technology." *The Bent of Tau Beta Pi:* 30 (Fall 2006). Available at http://www.tbp.org/pages/Publications/Bent/Features/F06Brown.pdf

down from a 20-year high of 4.0% in 2003. Changes between 1993 and 2003 in median real salary for recent S&E graduates indicate increasing relative demand for S&E skills during the past decade; the largest increases occurred for bachelor's degrees in computer and mathematical sciences (up 23.3%) and engineering (up 20.4%).

In addition, the importance of foreign-born S&Es to the U.S. S&E enterprise continues to grow. Data indicate that 25% of all college-educated workers in S&E occupations in 2003 were foreign born; 40% of doctorate holders in S&E occupations. The capability of doing S&T work has increased throughout the world: between 1994 and 2004, research and development (R&D) employment outside the U.S. by U.S. firms increased 76%. The proportion of women, blacks and Hispanics in S&E occupations continues to grow, but are still less than their proportions in the overall population: women were 12% of those in nonacademic S&E occupations in 1980 and 26% in 2005; blacks increased from 3% in 1980 to 5% in 2005; Hispanics from 2 to 5%.

3. U.S. Competitiveness in Science and Technology

A 2008 RAND report by Titus Galama and James Hosek explored the U.S. competitiveness in science and technology. The approach was to cite arguments made to support the contention of a creeping S&T crisis in the U.S. and then to contrast the arguments with relevant data and to consider them from different angles. The authors sought to address two questions:

1. What are the implications of globalization of S&T and the rise of other nations for U.S. performance in S&T?
2. What evidence suggests that the U.S. has been under-investing in S&T?

The report findings indicate that the United States continues to lead the world in science and technology. The U.S. grew faster in many measures of S&T capability than Japan and Europe, and developing nations, although developing nations are starting from a small base. The United States accounts for 40% of total world R&D spending and 38% of patented new technology inventions. However, potential weaknesses persist in under-performance of K–12 students in mathematics and science, and in the limited attractiveness of S&E careers to U.S. students. A heavy focus of federal research funding is on the life sciences. The diminishing shares of degrees awarded to U.S. cities, particularly doctorates and master's degrees, is a source of concern.

4. RAND's Rose-Colored Glasses

In response to the 2008 RAND report by Titus Galama and James Hosek exploring the U.S. competitiveness in science and technology, S. J. Ezell and R. D. Atkinson wrote a paper in September 2008, titled *RAND's Rose-Colored Glasses: How RAND's Report on U.S. Competitiveness in Science and Technology Gets it Wrong*.

The authors reflect that over the last several years a number of reports have raised concerns about U.S. S&T leadership. The reports have emphasized the growing challenge of rapidly developing Asian and European nations. Collectively, the reports are that U.S. faces intensifying foreign competition in S&T and that the country is falling behind key building blocks in the S&T base.

The authors state that the latest report, by RAND (Galama and Hosek, 2008) contains serious structural and analytic flaws:

- Framing the wrong question in the S&T competitiveness debate
- Providing an incomplete historiography of U.S. S&T policy development
- Using inappropriate benchmarks
- Failing to include key measures needed to deliver a true assessment of U.S. S&T competitiveness

The authors conclude that "The real question is whether the United States is acting sufficiently to maintain its lead in science and technology in the face of trends that show a clear deterioration in its lead in key metrics …"

5. Doctorate Recipients from U.S. Universities

V. Welch at the National Opinion Research Center at the University of Chicago conducts an annual survey of the doctorate recipients. The Survey of Doctorate Recipients (SDR) from U.S. Universities: Selected Tables 2007, Jr., 2008,[14] has 11 key tables that include the following:

1. Top 20 doctorate-granting institutions by broad field of study, 2007
2. Major field of study of doctorate recipients, 1977–2007
3. Number and percent of doctorate recipients by gender, 1977–2007

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14 See http://www.norc.org/projects/Survey+of+Doctorate+Recipients.htm

4. Doctorate-granting institutions with largest number of U.S. citizen minority doctorate recipients by race/ethnicity, 1997–2007
5. Citizenship status of doctorate recipients, 1977–2007
6. Top 30 countries/economies of origin of non-U.S. citizens earning doctorates, 2007
7. Doctorate-granting institutions having the largest number of non-U.S. citizen doctorate recipients, 2007
8. Percentage of doctorate recipients who earned a master's degree, 2007
9. Percentage of doctorate recipients who attended community college, 2007
10. Median years to doctorate
11. Median number of years from baccalaureate to doctorate

As an excerpt, the citizenship status of doctorate recipients by broad field, 2007 (1977 figures in red) are:

- Physical sciences
  - Total number = 8,037 (4,325)
  - U.S. citizens number = 3,488 (3,307)
  - Non-U.S. citizen, permanent resident = 388 (265)
  - Non-U.S. citizen, temporary visa = 3,662 (680)
- Engineering
  - Total number = 7,745 (2,643)
  - U.S. citizens number = 2,242 (1,477)
  - Non-U.S. citizen, permanent resident = 290 (326)
  - Non-U.S. citizen, temporary visa = 4,579 (780)

Appendix G.
Reading List

General Reading

Abrahamson, George. *Report of the Blue Ribbon Panel on Management Options for Air Force Laboratories*, 1993. http://www.au.af.mil/au/aul/aupress/Books/Duffner/Duffner.pdf (Chapter 5, pp. 71–74).

Adams, James D., Eric P. Chiang, and Jeffrey L. Jensen. "The Influence of Federal Laboratory R&D on Industry Research" (Working Paper 7612). National Bureau of Economic Research, March 2000. http://papers.nber.org/papers/w7612.pdf

Alba, Enrique, Gabriel Luque, and Francisco Luna. "Parallel Metaheuristics for Workforce Planning." *Journal of Mathematical Modeling and Algorithms* 6, no. 3 (September 2007): 509–528. http://www.springerlink.com/content/a6t408qw66k23666/fulltext.pdf

American Institute of Physics. "Chairman Wolf Urges Bush to Triple Federal R&D Funding by Next Decade." The American Institute of Physics Bulletin of Science Policy News Number 64 (May 4, 2005). http://www.spaceref.com/news/viewsr.html?pid=16474

Asch, B. J. *The Defense Civilian Workforce: Insights From Research.* RAND Report CT-208. Santa Monica, CA: RAND, May 2003. http://www.rand.org/pubs/testimonies/2005/CT208.pdf

Assistant Secretary of the Navy (Research, Development and Acquisition) Memorandum for the Director, Defense Research and Engineering. Subj.: "Alternative Naval Research Laboratory Management Structures," 17 October 1994.

Bard, Jonathan F., David P. Morton, and Yong Min Wang. (2007). "Workforce Planning at USPS Mail Processing and Distribution Centers Using Stochastic Optimization." *Annals of Operations Research* 155, no. 1 (November 2007): 51–78. http://www.springerlink.com/content/j3202742613311v0/fulltext.pdf

Bean, A. S., M. Jean Russo, and R. L. Whiteley. "Benchmarking Your R&D: Results From IRI/CIMS Annual R&D Survey for FY '96." *Research-Technology Management* 41, no. 1 (January–February 1998): 21–30.

Bean, A. S., M. Jean Russo, and R. L. Whiteley. "Benchmarking your R&D: Results From IRI/CIMS Annual R&D Survey for FY '98," *Research-Technology Management* 43, no. 1 (January–February 2000): 16–24.

Bomse, Frederick M., Brian McCue, Linda P. Harper, et al. *Navy/Industry Basic Research Study: A Final Report for Naval Analyses for N-091* (CNA Report No. CNA CRM 98-0279). Alexandria, VA: Center for Naval Analyses, 1998.

Broad, William J. "Government Reviving Ties to Scientists," *New York Times* online, November 20, 2001. http://www.nytimes.com/2001/11/20/science/government-reviving-ties-to-scientists.html

Cahlink, George. "National Security: Breaking the Code." Government Executive Media Group at GovExec.com (1 September 2001). http://www.governmentexecutive.com/features/0901/0901mag.htm

Campbell, Alan K., and Linda S. Dix (Editors). *Recruitment, Retention, and Utilization of Federal Scientists and Engineers.* National Academy Press, Washington, DC, 1990. http://www.nap.edu/openbook.php?isbn=0309043301

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REPORT DOCUMENTATION PAGE							*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE July 2009		2. REPORT TYPE Final					3. DATES COVERED *(From–To)* February 2008 – April 2009
4. TITLE AND SUBTITLE Assessment of the DoD Laboratory Civilian Science and Engineering Workforce							5a. CONTRACT NUMBER DASW01 04 C 0003
							5b. GRANT NUMBER
							5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Jocelyn M. Seng, Project Leader Pamela Ebert Flattau							5d. PROJECT NUMBER
							5e. TASK NUMBER AV-2-2928
							5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882							8. PERFORMING ORGANIZATION REPORT NUMBER IDA Paper P-4469 Log: H 09-000914
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of the Director, Defense Research & Engineering 875 North Randolph Street Suite 150 Arlington, VA 22203-1766							10. SPONSOR/MONITOR'S ACRONYM(S)
							11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. (28 July 2009)							
13. SUPPLEMENTARY NOTES							
14. ABSTRACT In response to a request by the DoD's Deputy Under Secretary of Defense for Laboratory Programs and Basic Science (DUSD/LABS), the Institute for Defense Analyses (IDA) analyzed trends in the DoD Lab civilian S&E workforce between 1988 and 2008 in five year increments. A customized database developed by IDA containing workforce information provided by the Defense Manpower Data Center (DMDC) was created to conduct the workforce analysis. Data were augmented by selected DoD lab director interviews, in part to understand the role of "Lab Demo" personnel policies. This report summarizes the study findings and recommendations.							
15. SUBJECT TERMS workforce, scientist, engineer, DoD laboratories, recruit, retention, retirement, occupation, demographics, Lab Demo							
16. SECURITY CLASSIFICATION OF:				17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES		19a. NAME OF RESPONSIBLE PERSON Dr. John W. Fischer
a. REPORT Uncl.	b. ABSTRACT Uncl.		c. THIS PAGE Uncl.	SAR	96		19b. TELEPHONE NUMBER *(include area code)* 703-588-1476

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18